

# SCHOOL SCIENCE AND MATHEMATICS

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## EDITOR FRANK B. WADE RETIRES

Dr. Frank B. Wade, Chemistry Editor for fifteen years, has been forced by ill health to give up his editorship. He will continue his teaching and administrative work as head of the chemistry department at Shortridge High School, Indianapolis, but will replace his many other activities by much needed relaxation. We are sure that we express the sentiment of all our subscribers in wishing that a few months' rest will enable Dr. Wade to resume at least a part of his many valuable extra-school activities.

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## MR. DRULEY PARKER CARRIES ON

For some months Mr. Wade has had the able assistance of his fellow teacher, Mr. Druley Parker, in carrying on his editorial work. Mr. Parker has shown such remarkable ability and energy that he was immediately offered the chemistry editorship on Mr. Wade's retirement. Although Mr. Parker is a young man he has had a rich experience. He has a Bachelor of Science degree from Purdue, an M.A. from Indiana University, and has done graduate work at Colorado and Michigan Universities. His teaching experience includes work at Franklin and Bloomington high schools and since 1928 in his present position at Shortridge. He was also critic teacher for Franklin College and for Indiana University while teaching in the high schools of the two college cities. He is a member of the Central Association of Science and Mathematics Teachers, The American Chemical Society, Indiana Academy of Science, Indiana High School Chemistry Teachers Association, and Indiana State Teachers Association. Mr. Parker takes his regular place on our staff with this issue.

## MISS VILLA B. SMITH, EDITOR FOR GEOGRAPHY

Another new name on our staff fills the vacancy in geography. Miss Villa B. Smith of John Hay High School, Cleveland, Ohio, holds two degrees from the University of Chicago and has an enviable teaching record both in the subject matter of geography in Cleveland high schools and in Western Reserve University and Kent State University and also in the teaching of geography in the Cleveland School of Education and the School of Education of Western Reserve University. Her contributions to this and other science journals, her radio lessons in geography, and her appearance on numerous educational programs have made her a leader in the teaching of geography. In her new capacity as our geography editor she will be glad to hear from geography teachers everywhere.

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### CONTRIBUTORS TO THIS ISSUE

Our first article this month is by the well-known science educator, Dr. Morris Meister, Principal of the High School of Science, The Bronx, New York City. Dr. Meister needs no introduction to our readers and to the thousands of pupils and laymen who have heard him lecture or have read his articles on modern ideas in science teaching.

Dr. John Leighly, Professor of Geography at the University of California, presents an easy method of teaching an important topic in meteorology.

Professor K. Gordon Irwin, Colorado State College, gives many sidelights on weights and measures in common use. His article will be of interest to all teachers and students of the basic sciences.

Mr. Charles M. Austin, Teacher of Mathematics in the Oak Park-River Forest Twp. High School and first president of the National Council of Mathematics Teachers, is the author of a timely article on "Motivating Mathematics," which was read before the Mathematics Section of the Central Association of Science and Mathematics Teachers, Nov. 25.

Dr. P. F. Brandwein, New York University, and the other members of the Committee on Techniques of the New York Biology Teachers' Association present a series of demonstrations for teaching photosynthesis.

School administrators as well as teachers of physics and chemistry should read the article on page 172 by John C. Hogg, Head of the Science Department, Phillips Exeter Academy and also "What the College Expects of an Elementary Course in Physics" on page 177 by Professor J. C. Slater, Head of the Physics Department, M.I.T. Other interesting articles are by Professor Whit Brogan, Northwestern University, Mr. E. B. Chrisman, Dayton High School, Dayton, Washington, Mr. Heber Mutch, Assistant Principal, Glen Rock, Pennsylvania, Mr. James D. Perdue, VanderLaan Junior High School, Muskegon, Michigan, Mr. W. D. Porter, Editor for Science Demonstrations.

## THE PROGRAM FOR SCIENCE IN 1950\*

MORRIS MEISTER

*Principal, The High School of Science  
The Bronx, New York City*

About six years ago, I agreed to read a paper before the Wisconsin State Science Teachers Association, dealing with the status of science teaching in the year 1999. I have had many reasons since then to regret my temerity. The most regrettable feature about the whole affair was that I did not rest satisfied with just *reading* the paper. After all, sound vibrations quickly turn to heat at a temperature which makes the energy unavailable for useful purposes. But, the editors of your excellent journal seemed to be desirous of printing the words. Now, the article can forever come back to plague me. I take it, that my presence here this morning is to provide you with an opportunity to watch me squirm as I try again to predict a future program for science—this time for the year 1950.

Of course, it is easy to indulge one's fancy and dream about a rosy future, just so long as we project ourselves far enough into time. However, in indicating a probable development for the next ten years, it is necessary to pay stricter attention to present realities. What, then, is our status in science education? What present conditions and modes of thought are of sufficient significance to cause change in the imminent future or determine the direction of growth and progress?

### AIMS AND VALUES

Nothing is of greater significance to a program for science teaching than the objectives we seek. The justification for nearly all that we do in the science classroom today can be found, I think, in three general aims of science teaching:

1. We wish to interpret for the child certain aspects of the world in which he lives.
2. We wish to give him an understanding of what we think are important ideas.
3. We wish to develop in him habits of reflective thinking and mental attitudes that resemble those of the scientist in his laboratory.

Although these aims would indicate a program of *general* edu-

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\* Read before the Annual Convention of the Central Association of Science and Mathematics Teachers, Chicago, Nov. 26, 1938.

cation, actually we seem to confuse our purposes with those of *vocational* education. Thus, what other interpretation can we give to our concern with meeting college entrance requirements? Similarly, much of our exploratory science work and many of our "practical" science courses seem to look too pointedly toward possible future vocations.

It is the opinion of the writer that the next ten years will clarify much of this confused thinking. Secondary education will be dedicated to general rather than to vocational purposes. This is not to say that we shall pay no attention to the problem of earning a living. On the contrary, science in common with other subjects will furnish a keener understanding of how livings are earned and of the special skills, knowledge and traits, mental and physical, that different ways of earning a living require. All this, in terms of a growing knowledge on the part of the individual of his own interests and abilities. Yet, the objective of our secondary schools will be the *good citizen* rather than the *efficient bread-winner*, the intelligent *consumer* rather than the skillful *producer*, the worthy use of leisure rather than immediate gainful occupation.

Thus, college preparatory courses will tend to disappear; for in a very real sense, such courses are vocational in their purpose. Besides, *all* children, rather than a selected *few*, now attend high school. Similarly, courses which train youth in too narrow a vocational field, will be either modified radically or they will drop out of existence. Industry and its methods are changing so rapidly that graduates of our vocational schools are likely to find themselves with skills for which there is no demand.

In support of this probable trend, may I quote from a survey just completed after three years of study, an expenditure of of \$500,000, and known as the "Regents Inquiry into the Character and Cost of Public Education in New York State."

What boys and girls now need is a broad general education which gives to all alike at least the same minimum essential tools of inter-communication and thinking, the same minimum up-to-date scientific acquaintance with the world in which we live, both natural and social, an appreciation of the culture and standards of our civilization, the beginnings of the ability to work with others, a common understanding and belief in the democratic process, and the desire to preserve and defend self-government.

On the subject of vocational training, the report continues as follows:

To make his way, as a practical matter, under this American system, what a boy needs vocationally is not so much "a trade" when he leaves school at age 16, 17, or 18, as a good general knowledge which underlies a family of occupations, an understanding of the scientific facts, and the economics lying back of these trades, the ability and character to work effectively with others, and an appreciation of the way changes come and how the individual may best adjust himself to them. On top of this, and taken at the very end, just before he has a real chance of getting a job, he needs an immediately marketable skill. When such a boy gets a job he will acquire the necessary, particular knowledge and dexterity on the job as a "learner." In some fields he may even come back to school for special courses organized in cooperation with labor and industry.

Another basic aim to which science studies will make a major contribution in the decade that lies ahead is the democratic way of life. This contribution will come as a sublimation of two present trends and will be forced upon us by a world situation.

First, is the trend toward teaching science for the development in pupils of scientific habits and attitudes. We do not know too much about this; our thinking is still rather vague and loose. Certainly, no well-tried and successful teaching procedures have emerged; but many of us are becoming quite emotional about the need for such habits and attitudes in our kind of government. Thus far, we have formulated tentative definitions, analyzed the kind of thinking and problem-solving which scientists do, and have tried to pattern our teaching of traditional science subject matter so that pupils go through the motions of arriving at conclusions based upon objective evidence. And, thus far, we are neither certain of our success in the field of science nor of the transfer of such attitudes as are developed to life situations of the broader kind.

Second, is the trend to stress the social implications of science. "Science and Social Values" is a popular theme with both scientists and science educators. Science is blamed for many of our existing social evils. In defense, we say that science is unmoral; it is a two-edged sword; it can serve rather than degrade humanity, if only man will learn to use science properly. But, does not such a response beg the question, If we are to learn to use science in the service of mankind, then the science teacher must do something about it; nobody else will. It ill becomes the teacher of science to play the role of the scientist. He may like to withdraw from the hustle and bustle of humanity to his laboratory or classroom there to deal with scientific truths in a calm, cold, dispassionate manner. But, he can not; he dare not. To him are not the prerogatives of the re-

searcher, the pioneer on the frontiers of knowledge, pushing back the walls of ignorance, dispelling mystery. Once and for all, let us admit that we are not scientists; we are teachers. If science has social value, if it can solve social problems, if man must learn to use science, if he is not to be destroyed by science, then we science teachers must act and act quickly.

Now, it is interesting to note that the two trends referred to above are converging to a single line of action; and that progress along that line is being forced by a critical world situation. Never before has the democratic way of life been so threatened as it is today. It has its maddened enemies who deride reason as a worthy attribute of mankind, preferring the violent and unscientific procedures of war for the solution of problems. Democracy also has its cynical friends who ask if self-government is ever more than make-believe, if there is wisdom in mass voting, if there is justice in majorities and who suggest that perhaps might does make right. In the wake of such questioning comes insidious prejudice toward race, color and creed—an intolerance of spirit that means the speedy death of science and its method.

What, then, can we expect as a reasonable outcome for a program of science teaching? Just this—We shall become propagandists for democracy. We shall frame courses of study, devise methods and organize curricula in science studies which consciously aim to make pupils *prefer* the democratic way of life. Pupils will learn to hate war because war is bad science; they will grow more tolerant because prejudice is unscientific; they will demand self-government because it is a scientific truth that tyranny degrades, enslaves and ultimately kills mankind.

#### THE CURRICULUM OF SCIENCE STUDIES —

The next ten years will, of course, bring changes in the curriculum of science studies. At the present time, we are no nearer our goal of a twelve-year sequence in science than we were in 1920. We urge our case as emphatically as we ever did. We make pretty blue-prints showing how six years of elementary science can be followed by three years of general science, and the latter in turn by a year of Biology, a year of Chemistry and a year of Physics. Yet, not a single generation of pupils has lived through the experience of such a sequence of science studies. That being the case, we really do not know what kind of general science we would offer to children who have had six years of the right kind

of elementary science. Nor do we know just what kind of Biology, Chemistry and Physics would be suited to pupils who had experienced the sequential learning of the preceding nine years of science. Actually, our courses in General Science assume little previous science learning. To a large extent, Biology, Chemistry and Physics develop their respective generalizations, as if pupils never had had contact with science subject matter before.

Hence, it is not difficult to predict that the future will bring a decided modification in grade placement of science concepts and subject matter. We are likely to find more and more of the material usually taught in senior high school grades, down in the junior high school grades, there to displace material that will seek lower levels still.

If it should be argued that difficulties of understanding, inherent in certain concepts, will prevent their displacement downward, the writer is inclined to reply as follows:

- (a) There are really only a small number of science concepts that involve difficulty of comprehension that can not be overcome by proper methods of teaching.
- (b) Sequential learning and a planned program of science experiences will make easy many things that now seem inordinately difficult.
- (c) For much of our present grade-placement there is not a shred of scientific evidence.
- (d) The history of much of our present grade-placement shows a gradual stepping down of concepts from college level to high school level to elementary school level.

The real reason why the downward displacement has not been operating very rapidly is that a twelve-year sequence in science has not been achieved. As a matter of fact, many are beginning to despair of success in this respect. Too many subject matters are pushing their claims upon curricular time. There is keen competition among subjects for what each describes as its "rightful place in the sun." Since this trend toward compartmentalization of the curriculum is being justly criticized, the next decade must bring about a new point of view toward organization in all subject matter areas.

The situation is especially critical at the secondary school level. Here, the competition among subjects is so keen that few students can find time for more than one year of science after general science. This is complicated further by the fact that the average boy or girl now in the high school is the average boy

or girl of our population as a whole. Because such pupils are not easily interested in the college entrance type of senior high school science, we say they are non-academically minded, unfit for real science study. In desperation, we organize "fused" courses, we treat subject matter descriptively, talking *about* science rather than studying science itself. Where will such tendencies lead?

In the opinion of the writer, they can lead only to a recasting of our curriculum. In this process, two points of view will emerge:

1. The subjects, as subjects, must be retained because they contribute to real pupil needs. There comes a time in every pupil's life when he needs the kind of organized knowledge which the traditional subject matters provide.
2. The content and treatment of subjects should differ with different groups of varying intellectual interest and ability. This may mean two or three kinds of courses called Chemistry, Biology or Physics. In large school organizations, this may lead to schools within schools or to smaller units each with a more or less homogeneous student body.

To meet the competition among subjects, the curriculum of studies must recognize the value of all contributions, with no sacrifice of any. How can this be done?

Let us for the moment assume that each major subject shall require four instead of five periods a week. After all, what basis other than that of tradition dictates the necessity that a major subject shall be given five periods a week? This opens at once the theoretical possibility that each of seven subjects can appear four times a week on a pupil's program without overcrowding his school day or his school week.

Theoretically then, each of seven subjects can develop a sequential series of offerings from its own field, beginning with the Freshman year and ending with the Senior year of the high school course. In order to study this result of such a proposal, let us picture seven horizontal lines, labeled Natural Science, Social Studies, English, Mathematics, Modern Language, Health Education and Fine Arts. Let us also picture four vertical spaces crossing the horizontal lines, one space for each of the four high school years. Reading vertically downward through any of the columns, we can examine the educational experiences of the pupil. Now, let us assume that the content of the subjects in any one column has been carefully selected so that it meets the following criteria:

1. That it fit horizontally in the sequence which subject matter experts have organized for the four years.
2. That its value be accepted not only by those who proposed it, but by the other subject matter departments.
3. That it be so inter-related that the pupil can live through a unified experience. In other words, the content from all areas, reading vertically, must be integrated around a number of vital life problems. Although the subjects will retain their identity, they can no longer be a heterogeneous collection of air-tight compartments.

Of course, it would be difficult to achieve such a program of studies without cutting away a lot of the dead wood in all the subjects. Time, too, would be saved by avoiding duplications. Since each department is given the right to approve or to disapprove what the other departments are offering toward the education of the pupil, the curriculum can not help but shrink to essential minimums. As a matter of fact, therefore, much curricular time is freed for "electives." It becomes easy to provide for individual differences. Surprisingly enough, no subject loses very seriously in total amount of curricular time, as compared with the present time-allotments. The great gain, particularly for the natural sciences, is that it makes possible the sequence of science studies which we have been urging for so many years. Furthermore, the natural science in any one semester can become the "core" of the curriculum for the pupils whose interests and abilities lie in that direction. In the same way, for pupils of different interests and capacities, other "cores" or nuclei can assume the integrating role.

The writer proposes such reconstruction of the curriculum as a probable trend for the next decade. The program in science can thus become a continuous experience growing out of and built upon the first eight or nine years of elementary science study. Furthermore, such a program in science is not isolated from other major fields of the curriculum. There is then no need that science shall compete with these other fields for its rightful place in the scheme of things.

It may appear to some that such a program is unduly conservative. Anyone enamored of the attractive philosophy set forth in the recently published work of the Progressive Education Association, "Science in General Education," will probably look toward a much more radical change in the teaching of science. One can not deny the potency of the "needs" of the adolescent as determiners of curriculum and educational values. Nor can one fail to admit that certain characteristics of

personality are more important goals than mastery of subject matter. Yet, most practical science teachers will admit, especially those who function in the large public schools, that the implementation of the "progressive" philosophy is as yet woefully weak. Indeed, things being what they are and teachers what they are, it will be closer to 1975 than to 1950 before anything like the "progressive" program in science can be realized, even admitting its soundness.

In summary, then, of the probable curricular development in science education, by 1950, we might list the following:

1. The achievement of a twelve-year sequence of science studies.
2. A more careful and comprehensive course in elementary science for grades 1 to 6, incorporating some of the material now found in the general science course.
3. A course in non-specialized science for grades 7, 8, and 9 which will continue the preceding science work to higher levels of experience and achievement.
4. A series of special science courses for grades 10, 11, and 12, which will lead on from general science.
5. These special science courses will be inter-related among themselves.
6. Especially important will be the relationships which the natural science courses will have with the other subjects in the curriculum. In some schools, and for some pupils, the science courses will become the core of the curricular experiences. In other schools and for other pupils the science courses will enrich and contribute toward the other subjects in the curriculum.

#### ARTISTIC TEACHING

With the change in philosophy and outlook and with the curricular developments described in the previous section, the year 1950 will bring marked progress in artistic teaching. Artistic teaching is here used in the sense of those procedures employed by the teacher which yield a maximum amount of learning on the part of the pupil.

It is interesting to note that the teacher of science has always been dependent upon concrete materials for effective results. Whereas, in an English or a History class, the teacher or a pupil is often the focus of attention, it is usually a natural phenomenon which occupies the center of the stage in a science class. The science teacher's art has always involved the intelligent, often clever, use of apparatus and equipment. Science and invention have forged new mechanisms for making abstract ideas simple and clear. All over the country, science teachers

have been creating and devising new mechanisms for teaching purposes. Also, more and more attention is being paid to proper techniques in demonstration teaching. As in the case of superb performers on the violin or at an easel, the masterpieces are susceptible of analysis and their techniques are capable of imitation, practice and mastery.

This trend to perfect the presentation of science concepts by way of the demonstration table will continue to grow. Aided by the development of adult education in which field science is often taught by lecture-demonstration, demonstration teaching will become a fine art by 1950. It is obvious, even today, that teachers pay more attention than they used to, to the kind of experiment they select, the way they arrange the apparatus, the order in which materials are presented, the devices for enlisting interest, creating problem-situations, furnishing evidence and for clinching conclusions. The science teacher of 1950 will be better trained in the artistic use of demonstration table equipment.

#### VISUAL AND AUDITORY AIDS BY 1950

In 1950, artistic teaching will have appropriated a great many of the newly developing visual and auditory aids to understanding. Slides and film-slides, movies and talkies, radio and perhaps television will all appear in the teaching-learning procedures of science classrooms. Every well-equipped science department will have its film library. Reels will be short—perhaps of five- or ten-minute duration. They will be used most frequently as demonstrations are now used—to bring into the classroom an educative experience that could not otherwise be obtained. The costly experiments, the dangerous experiments, the experiments that require too difficult or too specialized a technique, the phenomena that occur in 1/1000 of second or those that last a week, a month or a year, phenomena at the tops of mountains, in the depths of the sea, in the bowels of the earth and in other inaccessible places—all of them will be brought to our pupils by way of the screen.

Most important of all, these films will be organized educationally by educators; not by advertisers or by Hollywood directors. At the same time teachers will not try to assume the role of Hollywood directors and technicians. The educational films of the future will be the result of much closer cooperation between the motion picture industry and the science classroom.

As for radio education, we shall yet learn how to perform science demonstrations before the microphone so that the listener can "see" the phenomenon with his "mind's eye." It is strange that some of our popular radio comedians, who command audiences that number in the millions, should have learned before we did how to produce sounds that simulate sights. Ask yourself, next time you listen to Charlie McCarthy or Jack Benny, whether they do not succeed in giving you as clear a visual picture as they do an auditory one, of what goes on before the "mike." The great difficulty with our science programs "on the air," has been that they have neglected to utilize the one medium of science teaching which we science teachers have found to be essential to good teaching-demonstration experiments. Most of our radio programs in science are "talks," based falsely on the assumption that the radio can reach only the ear.

#### LEISURELY TEACHING

By 1950, we shall realize more fully than ever in the past (and we shall act on that realization) that artistic teaching is, above all, leisurely teaching.

Our courses of study will be much shorter than they now are. You can not engage in an incessant drive to "cover ground" and at the same time develop reflective thinking, habits and attitudes of the scientist and clear understanding of the big ideas in science. We have suffered from courses of study which are too long because we have been too polite with each other. Inquire into the committee procedures by which all of our syllabi have been constructed and what do you find? The favorite content of this teacher and the pet experiment of that teacher have both been retained because no one had the heart or the courage to say, "No!" Or if, as sometimes happens, the members of the committee are not over-polite to each other and engage in a bitter struggle for bits of subject matter, the emerging syllabus is still too long because it is a product of compromise, rather than of principle. The futility of this process as sound educational method is already becoming evident. The science course of study in 1950 will be short enough to permit of *leisurely* teaching.

#### MORE LABORATORY WORK

In my opinion, that famous issue: individual laboratory vs. teacher demonstration will be a dead letter by 1950.

Despite the so-called studies and investigations, laboratory teaching will receive a new birth; but the laboratories of the future will be radically different from those we know now. They will be more simply and more flexibly equipped. They will be places where pupils can really put questions to nature rather than little stalls where one manipulates things according to instructions printed in a manual or where one records "data" to prove laws that one knows already on the authority of the text.

The laboratories of 1950 will provide a place where the pupil can pursue truth in the manner of the scientist. They will embody the spirit of problem-solving as a teaching method. Pupils will go there, not once a week on Wednesdays; but whenever they encounter a problem that can be solved only in the laboratory. It will be a place where evidence is gathered; a place where it is essential that we record our observations faithfully.

#### EXTRA-CURRICULAR ACTIVITIES IN 1950

There are strong indications at this time that the science program in 1950 will give an important place to extra-curricular activities in science. The science club will become coordinate in value with the science class. The curriculum studies will be paralleled by a carefully planned program of extra-curricular activities. At other times and in other places, the writer has described the significant development of science clubs and science fairs in New York City. It is not necessary, therefore, to take time here to indicate the probable growth which such work might have in the next decade. However, a recent development might be mentioned because of its bearing on what might be termed the beginnings of a Science Youth Movement in this country.\*

#### OTHER CHANGES

Time does not permit a full discussion of other aspects of The Program in Science for 1950. A full hour at least, would be required for the presentation of present trends at the Junior College level and the resulting probable developments in science teaching for young men and women to the age of 20. Inadequate though it may be, permit the writer to say at least this:

\* This reference is to the work of The American Institute of the City of New York (60 E. 42nd St., N. Y. C.) which has recently launched a nation-wide movement toward the organization of science clubs.

- 1) General rather than vocational aims will control education in grades 13 and 14. Concern with future life-work will of course be heightened during those years; but only in the sense that earning a living is essential for the well-adjusted individual in a democracy.
- 2) The science offering in the Junior College will undoubtedly bring greater subject matter specialization; that is, if an adequate 12-year sequence can be established as a foundation upon which to build. I venture to say that the College Freshman Orientation course in Physical and Biological Science now being developed in many colleges will be found to be unnecessary and a waste of time.
- 3) The science teaching in Grades 13 and 14, in common with the teaching of other subjects will put great stress upon digging knowledge out of books and out of the records which scientists have made of their laboratory research. Such self-education with its concomitant training in good study habits will go hand in hand with an extension of the kind of individual laboratory work which we have urged for the high school courses in science.

#### TEACHER TRAINING

No discussion of this kind can be complete without a consideration of the problem of teacher-training. But again, time will permit only a word.

There are two great issues in this field today. First is the troublesome question, "How much content and how much method?" Second, is the question "Can the science teacher be better trained for his job in an academic college or in a teacher-training institution?"

In a sense we are dealing with only one question. Are we not ready to agree with these propositions:

- 1) That to know is not necessarily to be able to teach.
- 2) That one must know in order to be able to teach.
- 3) That one must know very very much more than the pupil in order to be able to teach.
- 4) That there is such a thing as an art of teaching.
- 5) That this art is capable of analysis, imitation, practice and mastery.
- 6) That only those who have themselves taught adolescent are qualified to deal with the art of teaching adolescents.
- 7) That the mastery of an art demands practice with real school and classroom situations.
- 8) That too much time has been spent on the question of *how* to teach.

If there is agreement on these propositions, then the teacher-training institution of 1950 will be a professional school and not an academic college; but like the school for doctors, the

school for lawyers and the school for engineers, the school for teachers will provide more study of subject matter and present a better balance between content and method.

#### CONCLUSION

I can not close without referring to a development in the science program in New York City in which our Board of Education has entrusted to me the chief responsibility. Two months ago, we opened the doors of a new school. We call it The High School of Science. It is the second in a series of secondary schools now being projected. The first was the High School of Music and Art.

Despite the special purpose suggested by the name of our school and by the fact that the student body is selected, we have much in common with other high schools. Thus, we seek to develop good citizens for the democratic way of life. We give pupils an understanding and appreciation of our cultural heritage. We provide certain basic knowledge and skills. We interpret the nature of the world and of society. We inculcate habits of critical and reflective thinking. We do our best to discover for each pupil the direction in which he may find his life work and an enriched leisure. We help him to maintain a vigorous physical and mental well-being. We deal, in fact, with problems in secondary education and we study its literature, its history, its philosophy, its aims and its procedures.

A high school of *Science* does not alter the goals, of secondary education. It does offer a different method of attack. If the attack is to succeed, we should begin with a clear conception of what the method is and what it implies.

Obviously, we need a definition. Examples of the very best definitions are found in the natural sciences. It is a noteworthy fact that the perfect definition of a scientific concept always comes not as a primary event, but as a final stage, after many preliminary definitions have been discarded as a result of experimental evidence.

Emulating the method of the scientist, we adopted a tentative definition of a *Science* high school. *It is a secondary school which capitalizes an interest in the sciences among adolescent pupils, for purposes of general education.*

The task of formulating the curriculum and procedures for such a school, with a somewhat selected student body, with a more or less free hand in choosing the faculty, with a reasonably

good equipment, and in a large public school system is the most thrilling adventure which the writer has ever experienced. It is too soon to say more at this time—we have only an entering class of 300 pupils. But, by 1950 we shall have had eight graduating classes to test the validity of the program for science which the writer has tried to outline in this paper.

## NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

### Twentieth Annual Convention

**GENERAL PURPOSE:** To provide authoritative and stimulating discussion of classroom problems so as to add zest to one's professional life and joy to one's teaching.

**GENERAL THEME:** Making Mathematics Teaching Function.

**DESIGNED FOR:** Arithmetic teachers in the grades, high school teachers of mathematics, and those who train mathematics and arithmetic teachers.

**PROGRAM:** The complete program will be found in *The Mathematics Teacher* for January. A partial list of speakers follows here:

1. *Two general sessions.* United States Commissioner J. W. Studebaker, W. W. Beatty, M. L. Hartung, and F. R. Moulton, Secretary A.A.A.S., banquet speaker.
2. *Two arithmetic sessions.* A. C. Rosander, F. B. Knight, H. O. Gillet, F. S. Breed, L. J. Brueckner, F. E. Grossnickle, C. L. Thiele, H. G. Wheat, G. M. Wilson, J. T. Johnson, W. A. Brownell.
3. *Four Junior and four Senior High School sessions.* W. S. Schlauch, Ira Davis, J. H. Hlavaty, Bjarne Ullsvik, H. E. Grime, Harold Fawcett, Gilbert Ulmer, Leroy Schnell, R. G. Wilbur, Alma Bower, W. O. Smith, J. M. Jacobs, Howard Whipple Green, W. E. Betz, E. R. Breslich, L. C. Karpinski, Martha Hildebrandt, Vera Sanford, Raleigh Schorling, and several others.
4. *One Teacher Training session.* J. P. Everett, L. H. Whitcraft, L. E. Boyer, W. W. Rankin.
5. *General.* Exhibits from Cleveland schools, luncheon and dinner meetings, group breakfasts, get-acquainted tea and many opportunities for professional contacts, for making new friends, and for exchanging experiences.

**TIME AND PLACE:** February 24 and 25, 1939, Friday afternoon and evening and Saturday 8 A.M. to 9 P.M. at the Carter Hotel, Cleveland.

**COMMITTEE ON LOCAL ARRANGEMENTS:** A. Brown Miller, Shaker Heights High School Chairman, H. E. Grime, Supervisor of Mathematics of Cleveland Schools, Vice Chairman.

## A SIMPLE METHOD OF DEMONSTRATING CONVECTION AND CONDENSATION

JOHN LEIGHLY

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Explanations of convective movements in the atmosphere by reference to the circulation produced in a room by an artificial source of heat were probably invented at the now remote time when the circulation of the atmosphere first became an appropriate topic of discussion in heated classrooms. They have remained a standard constituent of the ritual of instruction, surviving all changes in pedagogic theory and in the technology of heating buildings. But the conscientious teacher has always to qualify this time-hallowed comparison with a reservation imposed by the presence of a ceiling in the room; that is, by the presence of a mechanical barrier to vertical circulation that has no close counterpart, in the form of a solid surface capping a layer of air, in the atmosphere. There is, however, one type of meteorologic situation, probably commoner than is generally recognized, in which there is an effective "ceiling" in the atmosphere that checks convection: a distribution of temperature in the vertical such that warmer air overlies colder air, the distribution called, because on the average temperature decreases upward through the atmosphere, an inversion. If the inversion lies at a height above the surface of the earth such that there is a layer of air of some thickness below it, vertical convective movements within the layer below it proceed almost as if this layer were actually confined above by a solid ceiling like that which limits convection in a heated room. The processes that go on in a layer of air below an inversion are therefore well suited to demonstration by means of an indoor model. As will appear from what follows, several of these processes may be closely approximated in a model that is exceedingly simple to construct.

### TEMPERATURE INVERSIONS AND ASSOCIATED PHENOMENA

Figure 1*a* illustrates by means of a graph of temperature plotted against elevation the characteristic vertical distribution of temperature in the air along the California coast in summer. At this season there is a persistent inversion at a height of a few hundred meters above sea level that separates a layer of cool and moist air below from warm and dry air above. The equally

persistent summer "fog"—at low elevations stratus cloud rather than true fog—occurs just below the inversion. It is perhaps better to say that the layer of cloud is formed at the top of the moist layer of air, since when it is formed in late afternoon or evening it appears first just below the inversion and becomes progressively thicker by the extension of condensation downward. The daily cycles of warming and cooling, of condensation and dissipation of the cloud, and of convective movements within the moist layer are affected but slightly, if at all, by the warm and dry air above.

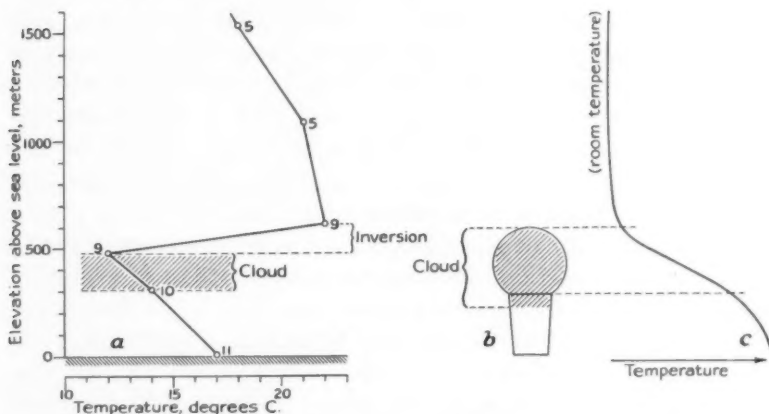


Fig. 1. *a*, results of aerologic flight at San Diego, California, Sept. 6, 1935. The full line shows the temperature of the air up to a height of 1600 meters; the numbers beside the plotted points give the specific humidity of the air at the several heights, to the nearest gram of water per kilogram of air. *b*, diagrammatic representation of the apparatus described in the text, showing the part of the apparatus in which a cloud is formed. *c*, probable vertical distribution of temperature in the apparatus.

This is not the only example that can be cited of an inversion that marks off a layer of air within which the meteorologic processes proceed as if below a ceiling. The Arctic Ocean in winter is generally covered by a layer of cold air below an inversion, in which, again, daily changes in temperature proceed independently of the warmer air above.<sup>1</sup> In lower latitudes and at greater heights there are inversions similar to the one illustrated in figure 1*a*, but less persistent, that may be recognized in the results of aerologic observations. Sometimes they can be recognized by the observer at the ground through the presence below them of certain kinds of cloud, notably the kind called altocumulus. These cloud layers are formed below inversions in much the

<sup>1</sup> H. U. Sverdrup, "The North Polar Cover of Cold Air," *Monthly Weather Review*, 53: 471-472 (1925).

same manner as is the summer "fog" of the California coast.<sup>2</sup>

Water vapor is always more abundant below these inversions than above them.<sup>3</sup> By checking the convective movements of air, an inversion also prevents water vapor from being carried upward through it, since it is just the upward components of convective mixing that perform the principal work of conveying watervapor up into the atmosphere from the surfaces of land and water from which it is supplied by evaporation. In figure 1a the water vapor content of the air is indicated by the numbers entered at each level for which temperature is plotted. These numbers give the specific humidity of the air at each level, rounded out to the nearest gram of water vapor per kilogram of air. The value 9 g. at the top of the inversion is certainly too high: the hygrometers used in airplane meteorographs have a considerable lag, and so do not react promptly when the instruments are carried out of the moist layer up into the drier air above the inversion. Probably 6 g. would be closer to the true water vapor content at this level than the 9 g. given by the observations. Not only water vapor, but also the minute liquid and solid particles collectively called haze are prevented by the inversion from being transported upward into the air above it. After the California coastal "fog" has been dissipated during the forenoon the inversion can still be recognized from an elevated point of view as a boundary between hazy air below and clear air above.

A layer of moist air overlain by dry air is in a position in which it may lose heat rapidly by outward radiation.<sup>4</sup> This is the process that leads to the formation of a sheet of cloud when the upper part of the layer of moist air cools below its saturation temperature. Whether or not the cooling is sufficient to produce clouds, loss of heat from the top of the layer of moist air is as effective in producing instability and convection within the layer as is heating at the bottom of it. Either cooling at the top or warming at the bottom, that is to say, may steepen the vertical temperature gradient beyond the dry adiabatic gradient of  $1^{\circ}\text{C}$

<sup>2</sup> A. C. Phillips and Sir G. T. Walker, "The Forms of Stratified Clouds," *Quart. Jour. Roy. Meteor. Soc.*, 58: 23-30 (1932); Sir Gilbert T. Walker, "Clouds and Cells," *ibid.*, 59: 389-396 (1933).

<sup>3</sup> There are also inversions that separate moist and warm air above from cold and dry air below: the warm frontal surfaces of cyclones are conspicuous and familiar examples. The clouds associated with frontal inversions are, however, produced by condensation in the air above the inversions, by processes difficult to imitate indoors, rather than in the air below them.

<sup>4</sup> The reader interested in pursuing the question of the heat economy of a layer of moist air below an inversion is referred to Sverre Pettersen, "On the Causes and the Forecasting of the California Fog," *Jour. Aeronaut. Sci.*, 3: 305-309 (1936), and Irving P. Krick, "Forecasting the Dissipation of Fog and Stratus Cloud," *ibid.*, 4: 366-371 (1937).

per hundred meters difference in elevation, and so make the layer below the inversion unstable.<sup>5</sup> When a layer of fog or cloud has a humpy or billowy upper surface, the humps and billows are generally evidence of convection within the moist layer in which the fog or cloud has been formed.<sup>6</sup> The forms of altocumulus clouds give similar evidence of instability in the relatively thin layers of air in which they are formed. Altocumulus clouds occur as sheets composed of patches or puffs of cloud. The individual patches and puffs show by their shape as plainly as do the more scattered cumulus clouds produced at lower elevations that they are loci of ascent and convection in unstable air. One may make the general statement that wherever a layer of moist air is overlain by drier air rapid loss of heat at the top of the moist layer may be expected. If the bottom of the layer cools less rapidly than the top—as in air over the sea, for example, where the air next to the water surface has a very small daily range of temperature—thermal convection and clouds of the cumulus type are common. Instability and convection resulting from cooling at the top of a layer of air are probably of as frequent occurrence over and near the sea as instability and convection resulting from heating at the bottom are over the land.

#### A MODEL SYSTEM

A layer of moist air capped by an inversion is very nearly a closed system so far as exchange of matter with its surroundings is concerned, though it is free to exchange heat with its surroundings through conduction and radiation. These qualities may be reproduced in a model constructed for purposes of demonstration. In the present reasoning the thermal inversion is considered as having a purely mechanical function, namely to serve as a barrier to movement of air upward or downward into and out of the system. In a model intended to imitate this natural system the inversion may, therefore, without placing too great a strain on the requirement of similarity between prototype in nature and indoor model, be replaced by a mechanical cover. If we are to have convection in the model system, a temperature gradient directed upward within it will have to be

<sup>5</sup> The temperature gradient below the inversion in the sounding plotted in figure 1a is about the dry adiabatic gradient, possibly slightly steeper.

<sup>6</sup> Almost any collection of cloud photographs provides examples of humpy and billowy upper surfaces of cloud sheets. Photographs of the California coastal "fog" taken from above that show evidence of convection within the cloud layer are reproduced in U. S. Weather Bureau, *Cloud Forms According to the International System of Classification* (2nd ed., Washington, 1928), fig. 11, p. 12; and in Alexander McAdie, *Clouds* (Cambridge, n. d.), plates IV and V.

produced. This is not a difficult task, since the gradient may be produced either by adding heat at the bottom or by removing it at the top. If in addition we are to have condensation in the upper part of the system copious enough to be easily seen, the temperature gradient will have to be steeper than is necessary if convection alone were aimed at. For the sake of simplicity

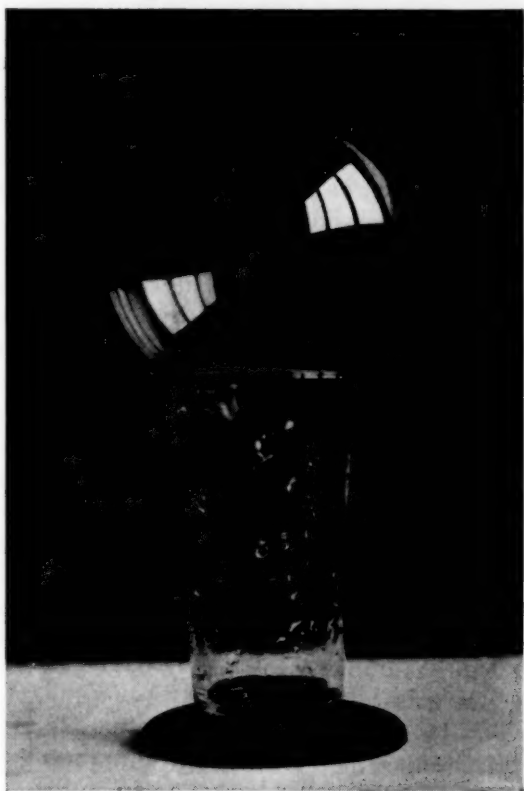


FIG. 2. Appearance of the apparatus described in the text. The camera does not catch the threads of cloudy and clear air involved in the convective circulation inside the bubble, but records only a rather uniform cloud.

of construction the temperature either at top or at bottom may conveniently be the temperature of the air in the room. Condensation will be most abundant if water vapor is condensed out of saturated air at a temperature higher than room temperature; convenience will then be further served if the temperature at the top of the system, to which the enclosed air is cooled, is room

temperature, and the temperature at the bottom considerably higher. The general structure of an apparatus that will fulfil the conditions of the experiment becomes evident: it will supply saturated air at a temperature considerably higher than room temperature at the bottom of an enclosed cylindric or prismatic space, and this air will be cooled to room temperature at the top, with condensation of a part of its water vapor. The higher the temperature of the saturated air at the bottom of the column, and the cooler the air in the room, the more copious will the condensation be.

One thinks immediately of a glass jar containing hot water, over the mouth of which a cold jar of the same diameter is inverted. One knows just as immediately what would happen in this combination: the inside surface of the cold jar would be fogged, and further developments within the system would be concealed from the inquiring eye. The cool upper part of the system should obviously be enclosed by a wall of some transparent material that will not fog. A material fulfilling these conditions is not easily found in the laboratory. But we have all been familiar since early childhood with certain hollow objects made of a transparent, non-fogging material that except for durability is perfectly suited to the present purpose; namely soap bubbles. A soap film is, moreover, thinner than any practicable solid wall, and so permits more rapid loss of heat from the cool extremity of the system than could be easily attained with ordinary laboratory material. The following simple procedure satisfies all the requirements of the experiment:

Put a plain glass tumbler into a pan of hot water deep enough to submerge the glass completely, and leave it there until it has become well heated. Remove it quickly, holding it mouth downward, and dip the open mouth into a soap solution so that a soap film is formed over the mouth. Insert a slender glass tube through the film into the interior of the glass, and blow through the tube until a bubble is raised above the mouth of the glass. Remove the tube, and set the glass down. If the bubble is inflated to a volume approximately equal to that of the glass on which it rests, as in the example illustrated by figure 2, it will be filled with a light cloud before the inflation is completed. At this stage the cloud is homogeneous, since blowing into the bubble effects a thorough mixing of the air in the apparatus. After the glass is set down the turbulence induced by blowing into the bubble dies out, and an active and regular convective circulation between

the warm interior of the glass and the cooler interior of the bubble is developed. Clear warm air rises into the bubble and cooler air filled with cloud droplets sinks downward from the bubble into the glass. As the descending air is warmed, the droplets carried in it are evaporated. The apparatus—if so absurdly simple an arrangement can be dignified with so learned a name—should be viewed in a good light against a dark background. Within it the processes are reproduced that go on in a layer of unstable air in the atmosphere when the ascending air is cooled below its condensation temperature: ascent is accompanied by condensation in the form of cloud, and descent is accompanied by evaporation of the cloud droplets carried downward. The glass remains warm enough to prevent fogging, the only obstruction to vision being the drops of water that adhere to it. The liquid film composing the bubble remains perfectly clear, since water condensed on it immediately becomes part of the film.

The water used should be as hot as possible. Dipping the hand into cold water before putting it into the hot water to take out the glass makes possible the use of hotter water than otherwise could be endured. The mouth of the glass should be dipped into the soap solution as quickly as possible, so that mixing of the hot saturated air inside the glass with the cooler and drier air of the room may be kept at a minimum. For blowing the bubble I find the glass tube of an ordinary medicine dropper satisfactory. The soap solutions sold for use with children's bubble-pipes yield slightly tougher bubbles than ordinary soap. In spite of all precautions, the film will sometimes be broken when the tube is pushed through it. It is well to have two or three glasses in the pan of hot water, to be taken out in regular order, so that if a film is broken the glass can be returned to the pan and a fresh hot one taken out. I find it convenient to have the pan under a hot water tap, with hot water running into it and overflowing into the sink at a rate sufficient to keep the glasses at the highest temperature at which they can be handled.

The bubbles last from one to two minutes: since water is constantly being condensed on their inside surfaces, the rapid evaporation from their outside surfaces is compensated, and they do not break promptly as a result of evaporation. The mouth of the glass shown in figure 2 has a diameter of 2 inches; it is difficult to get a soap film to form across the mouth of a much larger glass. If the bubble lasts long enough—and it usually does—the

cloud inside it is finally dissipated, the last of it to disappear being a thin wisp drifting about the top of the bubble. The glass and the air inside it lose heat rapidly to the air in the room, so that the temperature gradient between the air in the glass and the air in the bubble is evened out, and the convective circulation dependent upon this gradient gradually ceases. The cloud droplets disappear by merging with the soap film or with the water that adheres to the inside of the glass. Dissipation of the cloud in the apparatus is therefore the result of a process quite different from that which causes dissipation of a fog or cloud layer below an inversion in the atmosphere. In nature the dissipation is the result of warming from below until the temperature of the cloud becomes high enough to evaporate the droplets into the air in which they float.

#### MODEL AND PROTOTYPE

In figure 1*b* the combination of glass and bubble is drawn so as to place the cloud in the bubble in a position parallel to the cloud below the inversion in the atmosphere. In *c* of the same figure the probable distribution of temperature from the bottom of the glass up into the air above the apparatus is indicated. I am not able to draw a temperature scale for this curve, since I have made no measurements of temperature in the apparatus. In the early stages of the experiment the difference in temperature between bottom and top must amount to forty or fifty degrees C; so great a difference in temperature within a vertical distance of twelve to fifteen centimeters constitutes a temperature gradient much steeper than any that could develop under the natural conditions represented in *a* of the figure. But when viewed under favorable circumstances the processes that can be observed in a cloud layer formed in unstable air resemble closely those that can be seen in the apparatus described. In constructing a model it is always appropriate and convenient to exaggerate the rate of a process at the same time as its scale is reduced.

The following conditions are similar in the two systems represented in *a* and *b* of figure 1: loss of heat at the top, resulting in a steep vertical temperature gradient and active convection within the system; formation of a cloud at the top of the system as a result of cooling the air there below its saturation temperature; and a barrier that prevents mixing of the air in the closed system with the overlying drier air. If mixing with the overlying air occurred in either case, the temperature gradient and con-

vective movements would be weakened and the cloud dissipated through dilution with drier air. The principal differences between the two systems are these: In nature the system loses heat upward by radiation, while in the model heat is also lost by conduction, mainly through the soap film, but also through the walls of the glass. In the large-scale convection in nature mechanical changes in temperature resulting from ascent and descent of air are superimposed on the flow of heat from the ground into the layer of air below the inversion and out of this layer by radiation. In the model, on the other hand, the small scale of the convective movements makes such mechanical changes in temperature insignificant. While the mechanical changes in temperature determine the vertical distribution of temperature in the air below an inversion, they would not exist, and so would not affect condensation, were it not for the main flow of heat. Their absence from the model therefore does not detract greatly from the accuracy with which it reproduces the mechanism of convection and condensation below an inversion in the atmosphere.

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#### INTERNATIONAL CONGRESS OF MATHEMATICIANS

On invitation of the American Mathematical Society, the International Congress of Mathematicians is to meet in Cambridge, Massachusetts, September 4-12, 1940. It is hoped that this meeting will prove to be a great scientific occasion as well as a significant factor in international understanding and good will. The mathematicians of the United States and Canada sincerely hope that they will be permitted to welcome a large number of visiting mathematicians.

Six sections are tentatively planned for the presentation of papers: (I) Algebra and Theory of Numbers; (II) Analysis; (III) Geometry and Topology; (IV) Probability, Statistics, Actuarial Science, Economics; (V) Mathematical Physics and Applied Mathematics; (VI) Logic, Philosophy, History, Diadactics. The International Commission on the Teaching of Mathematics proposes to have a session in connection with the Congress.

These short papers will be preferably in one of the official languages of the Congress (English, French, German, and Italian), and will not exceed ten minutes in length.

Detailed information will be sent in due course to all members of the American Mathematical Society. Others interested in receiving information may file their names in the Office of the Society, and such persons will receive from time to time information regarding the program and arrangements.

Communications should be addressed to the American Mathematical Society, 531 West 116th Street, New York City, U.S.A.

## SCIENTIFIC FEATURES OF THE COMMON SYSTEM OF WEIGHTS AND MEASURES

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Why should we put so much emphasis upon the metric system and metric units in our high school physics and chemistry work? There would seem to be many teachers who are asking themselves that question. Few of our high school students will have any occasion to use metric units after leaving school; as adult workers they will not need them. Mechanical, civil and chemical engineers use the common system of weights and measures, not the metric one; and so do the architects, mechanics, merchants, and our other tradesmen and professional people.

It is of course true that those doing research work in physics and chemistry use metric units. But the high school teacher may well ask whether the training of research scientists should be a major objective for high school classes.

Nearly all of the physics and chemistry texts use metric units in the problems, some almost exclusively. There are teachers using these texts who seem to take for granted (1) that the common system is constructed upon a scientifically unsound basis, (2) that the common system is a hodge-podge of poorly articulated units, and (3) that there is no way of handling the common units decimally.

Even if these views were correct the question as to whether we should place more than a minor emphasis upon the metric system would still be open to argument. But are these views really correct? The present article seeks to re-examine the history of our weights and measures for new evidence on the matter—not in the spirit of controversy, but for constructive purposes.

In the earlier days of human history the units used for measuring length and distance represented something about the person's body, such as the width of a finger or hand, the distance that the outspread fingers could span, the length of an arm or foot, the distance of a step or of the reach of the outspread arms.

Almost from the very beginning there was an attempt to articulate the different units of length. There were to be exactly four spans to the yard, exactly four fingers to the hand, exactly three feet to the yard, exactly two yards to the fathom, exactly five feet to the double-step. In spite of such relationships there

was for a relatively long time no exactness about any of the lengths, the hands, arms and feet of people differing too much for that.

The need for a refined accuracy of measurement, a decision as to what should be the official length for some important unit, and a complete system of lengths ranging from small to large units, arose first in Egypt. Doubtless the great building projects of the Pharaohs demanded these things. Stones cut at distant quarries had later to be fitted accurately into their building positions, a matter requiring accurate measuring.

The main unit of length in the Egyptian system, as in that of other nations of the ancient Eastern world, was the cubit or distance from finger tip to elbow. Each cubit was divided into two spans, and each span into twelve fingers or digits. Unfortunately the cubit did not remain of exactly the same length in the long period of time that Egypt lasted as a nation. Nor was the cubit of Babylonia or Phoenecia of exactly the same length as that of Egypt.

After the decline of the Eastern nations the power of empire passed first to Greece and then to Rome. As soldiers and builders of engineering projects the Romans used the foot and pace (or double-step) as major units of length. Needing a small unit they divided the foot into twelve parts. In the language of Rome a twelfth part of anything was an *uncia*. In English speech the *uncia* of length was eventually to become an "inch."

In their military work the Romans used ten as a basic number. Soldiers were grouped by tens, by hundreds, and by thousands. For marching distance they had the *mille*, "a thousand," which represented a thousand paces. From this was to come the English word "mile." Since their pace was five feet the mile of the Romans was 5000 feet.

The foot as the unit of length represented the same distance everywhere in the Roman Empire. This had to be the case or there would have been infinite confusion. When the vast Empire collapsed and numerous independent states took over the territory the foot lost this uniformity of length. Eventually each European country re-established an official length for the foot, but unfortunately the different countries did not get together on the matter as to what that length should be. By the year 1500 there were in Europe almost as many different lengths for this unit as there were countries. Of these the English foot, which we inherited, was neither the longest or the shortest.

In England in 1500 there were many crafts using units other than the foot in connection with their work. As soon as the length of the foot was definitely established in an official manner the other units became defined with a simple whole-number relationship to it. This was true of the span, yard, fathom and hand. It was also true of the barleycorn of the shoemaker, the ell of the clothmaker, the chain of the surveyor, and the furlong (furrow-long) of the plowman. Of all the various units of length only the rod or pole had no such simple relationship to the foot. This unit was used to measure land areas, such as the acre. An acre was originally the amount of land that could be plowed by a yoke of oxen in a day—a rather variable size depending upon the condition of the ground and other factors. By the English statutes of Edward I, Edward III and Henry VIII the acre was officially set as equal in area to a space 40 rods long and four rods wide, and the rod was given the length of  $16\frac{1}{2}$  feet. A mile was also established as being 320 rods long, which made a square mile contain 640 acres. In that way our mile, intended for the farmer's use, became 280 feet longer than the 1000-pace mile of the Roman soldier.

There would seem to be nothing strange about the use of so many different units, each for some particular occupation. We do today the same thing that was done in that older time. The electrician gives the diameter of a wire in mils, the printer sets type by ems, the mathematician measures distances around a circle in radians, the physicist talks about Ångström units, the astronomer uses light years. The presence of such units in our systems of today does not bother us; we do not argue that their presence makes the system of measurement cumbersome and poorly articulated. Should we not take a similar attitude toward those units of the past that are now more or less obsolete?

When we turn to the subject of weight we may be expecting to find units whose size has been determined in a purely arbitrary manner. Investigation shows, however, that the weights in common use had a scientific basis of almost exactly the same nature as that used relatively recently in the construction of metric weights. That does not mean that, in the long time of human history, there were no arbitrary sizes used; the "stone" of the English, and the scrupulus, or "small stone," of the Greeks would indicate that crude weights may have been long in use.

It was probably in ancient Egypt and about 2000 B.C. that the first scientifically constructed weights were made. Their

plan was this. A container exactly one cubit high, one cubit wide, and one cubit long was constructed. This was filled with water, the weight of that much water to be the main unit of weight. This large unit was divided into 60 equal parts, and each of these into 1000 equal parts. The smallest unit was called a *gerah*; 20 *gerahs* made a *shekel*.

The Roman plan that gave rise to the weights of today was, in principle, exactly like that of the Egyptians. This plan used a container exactly one foot wide, one foot high, and one foot long. This they filled with rain water, calling the weight of water involved a *talent*. For smaller and more convenient weights the talent was divided into 1000 equal parts; 12 of these small units formed a *libra*. Since each of the small thousandth-part weights was a twelfth of something—in this case of the *libra*—it, like the twelfth of an inch, was called an *uncia*. In English hands the uncial-weight changed over into “ounce.”

No one would have needed accurate weights unless accurate weighing devices had already been invented with which to do the weighing. The Eastern nations used a two-pan balance like some in use today, as we can tell from the pictures on the Egyptian temples. Pieces of silver carrying some official mark were used as standard weights with these balances. In time these pieces of silver, carrying the picture of the ruler or some other distinguishing mark came to be employed both as weights and as money. Thus by the year 135 B.C. the shekel was both a weight and a coin. (Changes in the cubit's length would affect the exact weight of the shekel, so the coin of this name was not of entirely the same value throughout its history.)

In Roman times this policy of having a coin also represent a unit of weight was followed with silver coins. With the coins of smaller value bronze was used and the size of the coins was made greater for the sake of convenience in handling. For work with the balance the Romans found bronze more useful and stronger than silver in making the standard weights. Such bronze weight units were probably to be found in every army camp from one edge of the Empire to the other.

The Roman system of weights was not the only one in use in Western Europe. The Teutonic tribes, that were later to overrun the Roman Empire, had a weight unit that was somewhat larger than the *libra* that they called a “pond” or “pund.” This weight, made of iron, was not used with a balance but with a different weighing device called a steelyard (literally a “steel-

stick"). In weighing with this type of scales no smaller weights were needed, the iron weight being merely moved from notch to notch along the bar. The Teutonic people used this device in the buying and selling of fish and similar products, a use for which no extreme accuracy of weighing was either needed or required.

A confusion of words occurred where the Roman system and that of the Teutonic people came in contact. Part of the difficulty seems to have been due to the fact that the Roman word *pondere*, "to weigh," was so similar to the Teutonic word for their weight unit, the "pond." After the collapse of the Roman Empire both systems of weight continued in use as well as both types of scales used with these weights. Accurate weighing, like that needed for gold or silver, kept to the balance and the Roman weights of libra and uncia, while the iron weights and the steelyard were used for all common weighing.

As has been suggested pond was confused with *pondere*, and the pond with the libra, so the two weight units both came to be known by the same name. In England this name was "pound," in Germany "pfund," in France "livre," in Spain and its colonies "libra," in Italy "libbra."<sup>1</sup>

In England the larger unit—which represented the Teutonic pond—came to be called the "merchant's pound," or "avoirdupois pound" (which was French for "pound-of-goods"). The smaller Roman weight, which was but three-fourths as large as the other, was the "pound-of-silver" because it was used in weighing that metal. At Troy was the old English mint and it was there that all gold and silver for coinage purposes was handled; so the pound-of-silver was more often called the "pound-of-Troy." It was entirely logical that this "pound" should keep the abbreviation of L or LB, for it was really a libra.

The libra of the Roman system and the pound-of-Troy were alike in another respect besides their size. Each was used as the basis of the system of coinage, though neither was itself a coin, as a coin of that weight would have had no usefulness. When used for this particular purpose the Troy weight received the abbreviation £ which again was entirely logical.

In the Roman plan 20 shekels were equal to one libra; in the English plan 20 shillings were equal to one pound-of-money. But unlike the shekel the shilling did not remain equal in weight

<sup>1</sup> Ralph W. Smith, of the U. S. Bureau of Standards, *Scientific Monthly*, 38: 111-117.

to one-twentieth of the larger unit. The blame for that lay with the various kings who cut down on the quantity of silver they put into the coins. This debasing of English coins stopped with Queen Elizabeth, but by that time the weight of the shilling (and, of course, of other silver coins) was but one-sixth that of the original coins.

To return to the idea upon which the units of weight were based it will be recalled that 1000 ounces was the weight of a cubic foot of water. Any change in the size of the foot would cause corresponding changes in the size of the ounce, and therefore of both the libra and pound. England seems to have been more successful in keeping close to the Roman lengths and weights than was the case with most of the other nations. The uncia-of-weight of the Romans was equal to 437 of our grains. By the time of Queen Elizabeth a checking of the official ounces used in connection with ordinary weighing (that is, with the merchant's-pound and its ounce) showed that their weight was  $437\frac{1}{2}$  grains—a size they have kept ever since.<sup>1</sup> Had that extra half grain been left off, the weight of a cubic foot of water today would have been exactly that of 1000 ounces. According to Samuel Russell<sup>2</sup> the standard ounce is equal to 28,350.2 milligrams, while  $1/1000$  of a cubic foot of water that is pure and at its maximum density weighs 28,316.1 milligrams, the difference being almost exactly half a grain, for a grain is 64.8 milligrams. Although the difference between the weight of the ounce and that of the thousandth of a cubic foot is too small to be of practical importance in ordinary classroom work or in manufacture, yet it would be of importance in highly accurate work. Russell suggests that the ounce should be returned to its original size and be again exactly equal to the weight of  $1/1000$  of a cubic foot of water.<sup>2</sup>

The measuring of liquid capacity seems early to have been associated with weight. In England a pint of beer represented a pound of beer, and a pint of wine a pound of wine. The same idea was used with seeds and other things bought by measure. With the density of beer different from that of wine, and seeds less dense than either because of the open spaces between particles, the sizes of the pints were somewhat unlike. And what was true of pints was true of the larger units of measurement such as the quarts and gallons, or the quarts and bushels. What

<sup>1</sup> Sam'l Russell, *Science*, 58: 442-443, Nov. 30, 1923.

was wanted was a plan by which people would not be cheated when they bought and sold things. As it turned out the plan led to much confusion.

One-sixteenth of a pint was intended to be the capacity of an ounce of the substance measured, an idea that was correct if they measured wine with a wine-pint. The alchemists and apothecaries, however, began to use the idea with other liquids. They would measure out one-sixteenth of a pint of mercury or oil and call it an "ounce of mercury" or an "ounce of oil" just as if these amounts were weights. But liquids are easier to measure than to weigh, and the plan has continued; though we now think of an ounce used in this way as volume or capacity, and not as weight. Had the pint in use at that time held exactly a pound of water, then the fluid-ounce would have exactly equalled the capacity of an ounce-weight of water, and this would have made the plan a perfect one for scientific and technical purposes.

In this country we have never cleared up the confusion that came from pints and quarts of more than one size and have gone on using the wine and seed measures of old England. (Though we did leave out the beer quart!) The British Empire has been more modern and scientific than we, however, for their fluid-ounce has been changed to make it exactly the capacity of an ounce-weight of water measured at 62°F. This unit is used for both liquids and seeds. They have gone further and made the gallon the capacity of exactly 10 pounds of water, and the bushel of exactly 8-gallon capacity.<sup>3</sup>

Let us return for a moment to the idea of weight. There is only one legal pound-weight in England and only one in use in this country and that is the 16-ounce pound—which is not entitled to the abbreviation Lb. as it is not a libra and never has been. The ounce of this system is now being decimalized (just as the Troy-ounce had previously been decimalized in connection with coinage). Russell states that weights of the tenth, hundredth, and thousandth part of an ounce are now available to the trade, and fine balances graduated to tenths and hundredths of an ounce are being offered by manufacturers.<sup>2</sup> England is dividing its fluid-ounce decimally, and, of course, the fluid-ounce is itself a decimal division of the cubic foot.

Carrying on the thought of the decimalization of units, we

<sup>2</sup> Henry W. Bearce, of the U. S. Bureau of Standards, *Scientific Monthly*, 43: 366-368.

Ancient units of length, weight and money are discussed quite fully in *Oxford Cyclopedic Concordance* for Bible study. The Roman foot was 3% shorter than the English foot.

should notice that the mechanic has long been decimalizing the inch for purposes of accurate measurement, his "mike" giving readings to thousandths or smaller divisions.

No matter what our own personal attitude toward the metric system may be there is nothing in history to indicate that metric units are going to displace the common units either in this country or in other English-speaking countries. Evidence does point, however, toward a tendency to simplify the common system by dropping out-moded units and by the re-establishment of simple volume-weight relations. It also points to a growing use of the decimalization of the inch, ounce, and cubic foot to meet technical and precision needs.

There are relatively few difficulties in the way of a wider use of the common units in the science classroom. Present tables of density are just as correct if the heading reads "kilo-ounces per cubic foot" as they would if carrying "kilograms per liter" or "grams per cubic centimeter" as they do now. The "gram-molecular-volume of 22.4 liters" of the chemistry classes can just as accurately be expressed as "ounce-molecular-volume of 22.4 cubic feet," as the chemical engineer already knows.

For laboratory use we need certain changes in the calibration of equipment if we would use the common units, but these changes involve nothing really difficult. We need our foot rules and yard sticks with the inches divided into tenths and twentieths as the barometer already has them. We need to have weighing devices that will permit the decimal weighing of ounces. For capacity we need our graduates and burettes divided into decimal parts of the cubic foot, as England has done. That is all. I, for one, see no difficulties ahead if the metric system and its units of length, weight and capacity were entirely disregarded in our science courses, except as such units might be needed for college entrance examinations. Again speaking for myself, I would like to see the term "specific gravity" become obsolete in our science work. With density expressed in kilo-ounces per cubic foot there is no longer any need to distinguish the numerical values of specific gravity from those of density, and specific gravity could become "relative density."

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## MOTIVATING MATHEMATICS

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Mathematics should be motivated for the sake of the subject, for the sake of the teacher, and for the sake of the pupil.

All high school subjects are new and strange and abstract to the freshman. Algebra, especially, has a bad reputation among many people. It is only fair to the subject for the teacher to use some time to acquaint the children with its purpose and values.

Presentation by the teacher can be more easily done if the subject is first motivated and wrong ideas are dislodged from pupil's minds. If prejudices and misconceptions are all cleared away, the correct notion will have a readier acceptance by the pupil.

Every pupil is entitled to know why he should pursue any given study. Especially is this true when the subject is required of all students.

Some pupils begin the subject with a prejudice built up by outside influences. They will not do any worthwhile work unless this prejudice is broken down.

Other pupils think that the mathematical subjects are intended only for engineers and accountants and other like professions. So they will not do any effective study until they are shown that mathematics is universally useful and that it is the foundation science.

There are still other pupils who will not study anything with interest unless the subject is motivated; until they are shown that the time thus employed is not wasted and that such study really advances their value to the commercial world.

There is yet another class of pupils who are lazy and indifferent. Their interest must be aroused; their minds must be fired with a desire for this special brand of knowledge before study and learning can take place.

The clever teacher will soon discover the needs of the different pupils and apply the proper method for arousing interest and inciting study.

Even the best students will work with greater zeal if they fully understand and appreciate the many reasons why every person should master at least the elements of mathematics.

## 1. THE PURPOSE OF PLANE GEOMETRY

The main purpose of Plane Geometry in the high school is the teaching of the Analytic Method of Thought. In a few weeks or months most of the knowledge is forgotten even by the best students. So, if the method of thinking is not learned, then there is not much residue at all.

Geometry explains the method and then provides problems for the exercise of the method. If this be correctly presented by the teacher and learned and used by the pupil, it becomes a part of the pupil's mental equipment and remains with him through life.

It is valuable for anyone to be able to analyze a life situation, canvass its possibilities and implications, weigh the conflicting statements on each side and arrive at a correct conclusion. It is important to know when some one else—a lecturer or speaker or writer is using a false premise and arriving at a false conclusion. In short, thinking is the most important function of the human mind. A student may learn a large number of facts in any subject—history, sociology—but of what use are these facts unless he has some method of drawing valid conclusions from them. Geometry furnishes the method. This ability to analyze and to deduce new truths gives the educated person unlimited power over the great mass of knowledge in the world. Plane Geometry is the only high school course where this method is purposely taught and practiced.

W. S. Schlauch, writing in the *Fifth Yearbook* says: "Analysis is the method of discovery, and the only method of organizing the subject matter of geometry which gives sufficient command of the logical processes to justify its study."

Mr. Schlauch further says: "But to be truly initiated into the spirit and meaning of logical processes, he must acquire the mastery that comes *only* from analytic thinking. The mere committing to memory of the theorems and their demonstrations is not mastering geometry in this sense. The student has not reached this mastery until he has learned by analytic processes to discover proofs for himself and to assemble them in elegant deductive arguments. Only when he has received sufficient training to attack confidently a new proposition or problem, starting at the goal or conclusion, working backward step by step to his previously established body of truth, can he be said to have mastered the spirit of geometric reasoning."

On page 72 of his book on *How We Think*, John Dewey gives five distinct steps in thinking:

(1) A felt difficulty; (2) its location and definition; (3) suggestion of possible solution; (4) development by reasoning of the bearings of the suggestion; (5) further observation and experiment leading to its acceptance or rejection.

These five steps correspond very closely to the steps in the demonstration of a theorem in geometry:

<i>Dewey</i>	<i>Geometry</i>
1. The felt difficulty.	1. Statement of theorem or problem.
2. Its location and definition.	2. Statement of specific hypothesis and conclusion.
3. Suggestion of possible solution.	3. Pupil's analysis of problem.
4. Development by reasoning of the bearings of this suggestion.	4. Synthetic proof suggested by the analysis.
5. Further observation and experiment leading to its acceptance or rejection.	5. Statement of conclusion reached in Step 4.

## 2. MASTERY OF SUBJECT MATTER

Plane geometry is a large body of important knowledge in itself and it must be mastered if a student intends to do further mathematical study. Many colleges are admitting students now without preparation in mathematics. However, their field of study is quite limited. A student cannot even take a minor in agriculture without mathematics.

## 3. GEOMETRIC FACTS

(a) *Sum of angles of a triangle and other polygons.* This fact is the foundation of all pattern designs for tile floors, linoleums, etc. It explains why only certain regular forms are used for such designs. It is taken for granted that artists, designers, and architects must know this fact. Others should know it in order to fully appreciate the utility and beauty of their finished products.

(b) *Ratio and Proportion.* The facts of Ratio and Proportion should be matters of common knowledge and common use. How often their language comes into our every day conversa-

tion. These facts are taught in arithmetic, but students do not come into complete understanding of them without the study of algebra and geometry. Harry Burgess Roe, Department of Agriculture, University of Minnesota, in the *Sixth Yearbook* says: "The principles of proportion are essential, simple, and eminently useful. Proportion is the front door to variation and both are essential in chemistry and physics and engineering. The chemistry of today is hard for the average beginner anyway. Whether the administration is willing to admit it or not, beginning chemistry is an elimination course in the freshman year in many of our colleges. The teacher will make it doubly hard for the freshman by refusing to equip him with a comprehension and thorough knowledge of proportion and variation."

(c) *Pythagorean Theorem*. This fact was first used by the ancient Harpedonaptae—the rope stretchers of Egypt. They were the original surveyors. This fact is used not only by engineers, but by designers, plumbers, and mechanics of all kinds. Our pupils will not all appreciate the beautiful logic of the proof. However, when shown the immense practical value of this principle, the pupil will more readily study and use it.

(d) *Rigidity of Triangle*. This fact accounts for the use of the triangle as a support in buildings and bridges. Every garden gate, every garage door, stays erect because of the triangle in its construction. Roofs of houses and other buildings do not collapse because of their triangular supports.

(e) *Area Formulas*. These formulas express facts of common knowledge for every person, whether educated or uneducated. The farmer needs to know the area of his fields. The housewife wants new carpets and new decorations. To do an intelligent and thrifty piece of work, she must know how to compute areas and costs. In many ways and in many situations, these facts and principles enter our lives and work.

(f) *Similarity*. This principle lies behind map making and drawing to scale. The Pantagraph is an instrument used for drawing similar figures but of different sizes. Because similar triangles have equal angles, the relation of the sides of one triangle is the same as the relation between the corresponding sides of another triangle similar to the first. Thus, these relations known as sines, cosines, etc., can be computed and kept permanently in a table.

(g) *Measuring inaccessible distances*. It is said that Ahmes, when visiting in Egypt, surprised the king of that country by

his ability to measure the height of the pyramids by means of his walking stick, and some shadows. He simply measured the shadows of the stick and the pyramids made at the same time of day. Then, knowing the relation existing between the sides of similar triangles, it was easy for him to compute the required height. Because the corresponding sides of congruent triangles are equal, many inaccessible distances may be approximated.

(h) *Principles of Construction.* The construction principles learned in plane geometry are taken over bodily by mechanical drawing, art, architecture, and design.

(i) *Navigation.* Here, arithmetic, algebra, and trigonometry play a large part. Some of the instruments used by the navigator are: dividers, parallel ruler, protractor, universal drafting machine, speed instrument, mariner's compass, the mooring board, the chart, barometer, thermometer, log book chronometer, and sextant. Everyone requires a knowledge of mathematics in construction and use. Imagine one of the big ocean liners setting out on a voyage across the Atlantic without these instruments and without skilled men to use them. Of course, someone will say that Columbus had only one of the above—the mariner's compass. But it is also said of Columbus, that when he started he did not know where he was going, that when he got there, he did not know where he was, and that when he got home, he did not know where he had been.

(j) *Design and Decoration.* Geometrical figures are regular and symmetrical. They readily lend themselves to design and decoration. Regular figures are beautiful and many are easily fitted into patterns. Irregular figures are hideous, difficult to construct, and do not easily fit together. Many commercial articles—watches, clocks, bottles, vases, tables, compacts, etc., are made with geometric forms because those forms are both practical and beautiful.

(k) *Architecture.* This is a fertile field for geometrical application. Mathematics is involved in every part of a building. The floor is a square or a rectangle or a circle. The walls are rectangular, the windows are rectangular or circular or Gothic. The doorways are plain rectangles or rectangles surmounted by circular or Gothic arches. Triangles, squares, hexagons, circles and other geometric figures abound in the construction and decoration of churches, cathedrals and other public buildings.

(l) *Nature.* Nowhere are geometrical forms more in evidence

than in nature. The trunks of trees and the stems of plants are circular; the cell of the honeycomb is hexagonal; the sun and the moon and the planets are spherical; the dome of the heavens is a hemisphere; the path of the earth around the sun is an ellipse; the spider web has a geometrical pattern; the snowflakes are symmetrical with foundations of triangles and hexagons; quartz crystals are hexagonal prisms with pyramids on the bases; alum, gold, and magnetic iron crystals have the shape of the octahedron; zinc crystals have the form of the tetrahedron; salt and lead are found in the form of the cube; many flowers are circular in form; many fruits—oranges, lemons, grapefruit, apples, grapes, walnuts, are spherical or have a circular cross section. Someone has said, "God eternally Geometrizes."

#### 4. PRECISE AND ACCURATE USE OF WORDS

Nowhere is correct language so necessary as in geometry. One word wrongly used in a sentence destroys the thought intended. Every word has definite and specific meaning. To be successful, the student must grasp those meanings accurately. If the hypothesis is not correctly understood and stated, the conclusion will be false or impossible. The study of geometry should help the student in learning and using good English.

#### 5. NATURE OF PROOF

A proof consists of statements and reasons following each other in regular order. The statements must have a logical order. If one is omitted, there is not any proof. If the statements are not supported by reasons, the proof is weakened or destroyed. If a false premise is employed, then a false conclusion is reached. Practice in proving theorems and original exercises should help pupils to marshal facts and supporting reasons in the exposition of any topic. This kind of work should also enable a student to detect flaws in the reasoning of a writer or a public speaker.

Many slogans or catch phrases in advertising are based on false assumptions.

"Eventually, Why not Now?" is based on the assumption that sooner or later everyone will use Gold Medal Flour. This assumption is not true because many people never use Gold Medal Flour at all.

The slogan, "When Better Automobiles are Built Buick Will

Build Them," is based on the assumption that Buick is already building the best automobiles. Of course other companies would very vigorously dispute that assumption.

#### 6. INDIRECT PROOF

This is valuable in many life situations. It is studied and practised only in the study of geometry. Jevons, one of the great authorities on logic, goes so far as to say that "Nearly half of our logical conclusions rest upon the employment of indirect proof." Milne, in his revision of De Morgan's *First Notions of Logic*, states that the process of Reductio Ad Absurdum is of the greatest importance. It is the most prominent of all the methods by which men learn those truths of Nature that are unitedly known by the name of science.

#### 7. DISCOVERING NEW TRUTHS

Analysis furnishes the student with a tool for discovering new truths. Facts and principles from literature, from history, and from daily life are continually crowding in upon us. In the main they are noted and then forgotten. The individual who, by his power of reasoning can take these facts, and then produce new truths and principles, benefits not only himself, but all mankind. For centuries people had seen objects fall from a height, but only Newton could formulate the law of falling bodies. Countless people had seen liquids overflow a vessel. but only Archimedes could see and grasp the law. So it has been all through the centuries with every invention and original thought.

#### 8. SYMMETRY OF FORM

Regular geometric figures are symmetrical and therefore beautiful. Windows and doorways and buildings of all kinds are made with these geometric figures. Nature also is full of these same forms. Therein does their beauty lie. Many people go through life never seeing the beautiful things about them, or seeing the beauty, do not comprehend the reason for its existence. Irregular figures are not beautiful, and they are not used in building or decoration. In a course in plane geometry, these regular figures are constructed and studied. The pupil becomes familiar with their qualities, and is then able to see and appreciate their beauty. Professor Cassius J. Keyser of Columbia University, writing in the *Sixth Yearbook* says: "Beauty is the most precious and the most vitalizing element in the universe.

More than ought else it is beauty that not only makes life worth living, but makes it possible; for if by some spiritual cataclysm, all the beauty of nature and all the beauty of art and all of the beauty of thought were suddenly blotted out, our human race would quickly perish by depression of spirit, owing to the omnipresence of ugliness."

#### ALGEBRA

Algebra is the language of science. We are living in a scientific age where all things are placed on a scientific basis. Professor Harry Burgess Roe of the University of Minnesota, in the *Sixth Yearbook* says: "It has always been difficult to understand the antagonism displayed by many people to the idea of acquiring mathematical knowledge and understanding; for whether or not one recognizes or acknowledges the fact, we live in a scientific cosmos in which the fundamental governing forces all act in accordance with definite law. Law is the idea whether expressed or implied, of the method of orderly progress, and orderly progress is mathematical in its very essence. Hence, no one can escape the continual influence of mathematical principles in his life experience, no matter how much he may claim or seek to do so."

The simplest work in physical science contains formulas, simple equations, and graphs. Even the social sciences require the help of algebra and calculus when one gets beyond the elements. A subject becomes scientific only when it becomes mathematical. J. Arthur Harris of the University of Minnesota, writing in the *Sixth Yearbook* says: "The natural sciences all had their beginnings in observation and speculation. Careful description of the observed phenomena then furnished a basis of interpretation by comparison. Experimentation, which requires not only merely controlled conditions, but measured consequences, followed observation and description. Finally quantitative measurement, calculation and the formulation of mathematical laws have characterized the highest state of scientific development."

Algebra is occupied with symbols and symbolic thinking. At first, progress was slow, because there were no symbols. The first symbols were invented about 300 B.C., but it was not until the sixteenth century that a complete system was ready for use. Before that time there was no science because there were no symbols with which to express its conclusions. Formulas

were impossible without symbols. In the relatively short time since the invention of Vieta, the progress both in mathematics and in the other sciences has been swift and sure.

#### NUMBER SYSTEM

Our number system is superior to any other. With only ten characters, all numbers may be written. Other systems required separate characters for every number. The invention of the zero and the place value about the fifteenth century brought the decimal system into general use. This system made computation possible. Then ten characters could be substituted for a multitude; then a simple comprehensive and universal system could be substituted for the old confusion. Then computation could be done; relations could be expressed; scientific conclusions could be written in definite and final form; measurements of all kinds could be recorded; rules and directions could be written in brief and concise form. At last a universal scientific language had been invented.

Dr. Judd in the *Third Yearbook* writes: "Our present-day civilization is one which depends on the universal recognition of the importance of the idea of precision. Every machine which serves us in daily life is precise in its construction; every engagement of life is precise in its temporal arrangement; every economic relation, if it is to be just and acceptable to all concerned, must be precise. Precision is the soul of science and of commerce. As contrasted with civilization, primitive life is characterized by its lack of precision. Savages do not know how to be exact; they have habits of thought and action which the modern man must regard as absolutely intolerable in their loose and vague character."

Dr. Judd is only saying that the savage is not precise because he does not have a number system. We are exact because in our life we have a perfect number system.

#### MATHEMATICS INTERPRETS OUR ECONOMIC AND SCIENTIFIC ENVIRONMENT FOR THE INDIVIDUAL

W. S. Schlauch writing in the *Third Yearbook* says: "A cultured man is one who is at home in the world; to whom the universe and its changes cause none of the terror due to ignorance. In attaining this intimate familiarity with cosmic, economic, and social forces and laws and changes, mathematics is the one science that makes possible exactness in our interpre-

tations, that enables us to formulate with precision and to predict with certainty."

Here are over one hundred questions, the answers to which are mathematical. The list might be extended indefinitely. These questions show us how greatly we depend upon mathematics for the interpretation of our environment.

- (1) What is the horse power of your automobile?
- (2) How far will an object fall in a given time?
- (3) How high is an object such as a house or tree?
- (4) If regular deposits are made in a bank, how much money have you at the end of a given time?
- (5) How far away is the moon? The sun?
- (6) Given certain plans and measurements, how much material will be needed for erecting a building?
- (7) Why can only certain polygons be used in a tile floor or linoleum pattern?
- (8) What interest rate will your stocks or bonds yield?
- (9) What monthly payment is necessary to discharge a given debt in a given time? (Of course interest and carrying charges are included.)
- (10) What is the amount due on a certain sum at compound interest for a given time at a given rate?
- (11) Why are cathedrals and other great buildings beautiful?
- (12) In crossing the Atlantic, why do ships and airplanes go northward past Newfoundland?
- (13) What is an annuity?
- (14) What is the velocity of light?
- (15) Explain the changes of seasons.
- (16) How may a place be located definitely on the surface of the earth?
- (17) What is longitude? Latitude?
- (18) How much carpet is required to cover your floor?
- (19) What is the area of your state?
- (20) Compare the size of Germany and the United States.
- (21) What is the area of the largest state?
- (22) What is the population of Japan?
- (23) What is the size of your building lot?
- (24) What do you pay for an article costing \$50.00 with a discount of 3% for cash?
- (25) How long will you require for a 1,000 mile trip in your motor car?
- (26) How many gallons of gas will you use?
- (27) What will the trip cost you?
- (28) What is your life expectancy?
- (29) How large an annuity can you buy?
- (30) How much insurance can you carry?
- (31) How long do you expect to work?
- (32) What do you estimate your life earnings to be?
- (33) What is your annual budget?
- (34) What was your golf score yesterday?
- (35) What was the length of your best drive?
- (36) How far from town is your club?
- (37) In what direction is your club?
- (38) How many states in the union?
- (39) How many votes in the Electoral College?
- (40) How many are required to elect a president?

- (41) How many presidents have there been?
- (42) How long have you been married?
- (43) How many children have you?
- (44) How old are they?
- (45) What time of day is it?
- (46) When does your vacation start?
- (47) How old is your dog?
- (48) What is the size and gauge of your gun?
- (49) How many ducks are you allowed to kill?
- (50) How far away is your summer cottage?
- (51) How large is lake Constance?
- (52) Where is your farm?
- (53) How much did you have to pay for it?
- (54) What is the amount of the mortgage?
- (55) What annual payment do you make to retire the loan in ten years?
- (56) What is the size of your farm?
- (57) How many acres each year do you plant in wheat, corn and oats?
- (58) What is your gross income?
- (59) What is your net income?
- (60) What per cent does this income give you on the money invested?
- (61) How much are the taxes on your farm?
- (62) What is the tax rate in your county?
- (63) How is this rate computed?
- (64) How much is your income tax?
- (65) What exemption does the head of the family have?
- (66) What rate is paid on the balance?
- (67) When did you return from your trip abroad?
- (68) What length of trip did you have?
- (69) What did your trip cost you?
- (70) How much did you pay for that beautiful statue you bought in Florence?
- (71) 500 lire? Well, I mean, how many dollars?
- (72) What is the rate of exchange in Italy now?
- (73) How old is your son, Jim?
- (74) Starting on his first birthday, what monthly deposit do you make so that you will have on his eighteenth birthday a sum of money sufficient to pay for your son's college education?
- (75) How did you determine this monthly deposit?
- (76) How much do you deposit weekly in your Christmas Savings account?
- (77) To what will this sum amount?
- (78) How is it computed?
- (79) How are measurements made?
- (80) How were these measures—yard, foot, and mile—devised?
- (81) How was the length of the meter determined?
- (82) Describe the Metric systems of Measure.
- (83) What is the basis of the system?
- (84) How accurate are ordinary measurements?
- (85) How much coal do you burn each year?
- (86) About how efficient is your heating plant?
- (87) When the standing of a baseball team is given as .875, what does it mean?
- (88) How is that standing computed?
- (89) What are the shapes of windows, doors and buildings?
- (90) Why aren't irregular shapes used instead?
- (91) What shapes are used for watches, vanity cases, etc.?

- (92) Why did Plato want all of his students to know Geometry?
- (93) What law governs the best size for a framed picture?
- (94) How may one determine the amount of light that will fall on a given surface?
- (95) How determine accuracy?
- (96) How can the efficiency be determined?
- (97) What effect does the elliptical orbit of the earth have upon our lives?
- (98) What is characteristic of Gothic architecture?
- (99) Why are counting and measuring so important?
- (100) How are comparisons made?
- (101) What is meant by average?
- (102) How are statistics of various kinds always represented to obtain a good effect?
- (103) What is Solar time?
- (104) What is Standard time?
- (105) What is the velocity of sound?
- (106) What is Bank discount?
- (107) How are measurements recorded?
- (108) Other things being equal, which is the more expensive—oranges three inches in diameter at ninety cents a dozen, or oranges two inches in diameter at thirty-five cents a dozen?

This interpretation is further shown if one examines a few books on non-mathematical subjects. In a book entitled *Twins*, I found ninety-six tables, thirty-three graphs, forty-five equations and nineteen formulae. There also occur frequently the words correlation, function, variation, median, standard deviation, and all the other terms that enter into a statistical discussion.

*Fortune Magazine* for August, 1937, contains an article on "The Building Cycle," which is profusely illustrated with graphs.

In the *American Hairdresser* for December, 1931, is an article on "The Sinusoidal Currents and Their Effect on Your Patrons." It gives numerous drawings showing the sine curve.

The same magazine also contains an article on "Adjusting Accounts."

Mathematics requires precise and accurate statements and work. Two plus two must always equal four. The square on the hypotenuse of a right triangle is always equal to the sum of the squares of the other two sides. So, if the subjects be correctly taught and studied, the pupil can scarcely escape some training in neatness, accuracy, and exactness and other qualities which characterize mathematical work.

Elementary mathematics is nothing but the plainest common sense. The principles taken singly are very simple and easily learned.

In the Tree of Knowledge pictured at the Century of Progress,

mathematics is placed at the bottom, as being the foundation root of all knowledge.

Surely two years is little enough time for an educated person to give to such an important field of learning.

Recently the University of Wisconsin decided to admit students without a requirement in mathematics. Such students can major only in literature, history, journalism, and special courses such as art history, art education, and music. Such students are not allowed to even minor in the College of Agriculture, nor in the College of Education.

In 1924, the College of Business Administration, of Boston University after investigation, issued the following figures:—

(a) Untrained man begins work at 14, reaches his maximum income at age of 30, about \$1200 per year.

Total average lifetime earnings—\$45,000

(b) High School graduate begins work at age of 18, reaches maximum income at age of 50, about \$2200

Total average lifetime earnings—\$78,000

(c) College Graduate begins work at age 22.

Total average life time earnings \$150,000

The *Daily News* for September 24, 1934 gave these figures:

High School Graduate.....	\$ 88,000
College Graduate.....	\$180,000

This is a pretty good showing for the value of our present education. These figures are for the average man. Of course, some earn more. On the other hand, some earn less.

President Hutchins of the University of Chicago in *Harper's Magazine* for November, 1936, in telling what the course in general education should include says: "It remains only to add a study which exemplifies reasoning in its clearest and most precise form. That study is, of course, mathematics, and of the mathematical studies, chiefly those that use the type of exposition that Euclid employed. In such studies, the pure operation of reason is made manifest. The subject matter depends on the universal and necessary processes of human thought. It is not affected by differences in taste, disposition, or prejudices, It refutes the common answer of students who, conformable to the temper of the times, wish to accept the principles and deny the conclusions. Correctness in the thinking may be more directly and impressively taught through mathematics, than in any other way."

Concerning the importance of thinking, Mr. L. A. Hawkins, writing in *Science and Education* said: "Untrained minds are unable to cope with the natural emotions and prejudices which

sway us all. They cannot free themselves from bias, nor distinguish wishful thinking from the truth. They are unable to weigh evidence, to distinguish fact from appearance, to judge the validity of traditional beliefs, to adjust their thoughts and ideas to rapidly changing conditions. They are an easy prey for the demagogue, the opportunist, and the charlatan."

Duncan Clark, in a recent issue of the *Chicago Daily News* said: "In a democracy the mass must be taught to think. If the ideal of democracy is, as we in America believe, the highest ideal for a political system yet attained by human intelligence, then it can stand thinking. It can be saved by thinking. It cannot forever stand ignorance, prejudice, grasping self-interest, and the conflict of privilege-seeking pressure groups."

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## THE TEACHING OF ELEMENTARY PRODUCTS AND FACTORS

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The teaching of factoring in elementary algebra is closely linked with the multiplication of binomials by binomials. In the textbooks I have examined and used, the method of grouping and teaching is very similar.

Products are usually divided into four or five types and in much the following order: Type I,  $(a+b)(a-b)$ ; Type II,  $(ax+b)(cx+d)$ ; Type III,  $(a+b)^2$ ; Type IV,  $(a-b)^2$ ; Type V,  $(x+a)(x+b)$ . Types III, IV, and V, are either expressed as special cases of Type II, or are assumed as such by their method of treatment. In some texts, Types III and IV are considered one type.

The method of treatment is similar also. For Types I, III, and IV, an example is worked and is followed by a rule. For Type II, an example or two is worked showing cross products, and an explanation is given. For Type V, an example is given, showing in detail that the coefficient of the middle term of the product is the algebraic sum of  $a$  and  $b$ , and then follows the rule.

There are thus for the pupil four or five separate and distinct types of products to recognize, and a rule, more or less similar, but nonetheless distinct, to remember for each. The fact that

some types are special cases of others is too fine a distinction for the average or below average pupil to grasp or retain.

For several years I followed this same general method with unsatisfactory results. A great amount of drill was required to help the pupil keep the five types distinct and to remember the rule for each. Valuable time was thus misspent, and the pupils had a tendency, in spite of all the drill, to avoid the mental calculation, preferring to carry out the actual multiplication, when undetected.

For the last several years, I have changed this method with much more satisfactory results. The five types of products are reduced to two. Type I includes all binomial products whose first or second terms are equal, including sign; Type II includes those in which neither the first nor second terms are equal.

Since the present text follows the old order of grouping, I use the list of problems given, but not in the same order nor by the same rule. I start with a problem of Type I, say  $(x+3)(x+4)$ , and show how the product can be found mentally with little effort, stressing the fact that the middle term of the product is the algebraic sum of the unequal terms times one of the equal terms. This is then stated as a rule to find the middle term.

After suitable drill on products of this type, it is a simple matter to show that the rule holds for a variety of types, as  $(x+a)^2$ ,  $(x-a)^2$ ,  $(a+x)(b+x)$ , etc. All these types, and others, can be introduced in one period, as I have occasionally done, or in succeeding periods, which seems preferable. Strictly speaking the rule does not hold for square products, since both terms are equal, but pupils have no difficulty, if a simple explanation is given.

Products of Type II are treated by the usual method and taught last.

This simplification is logical and pedagogically sound. The number of types is reduced; the pupil learns the easier type first, and the more difficult one is reserved till last, instead of having them all mixed. Also the results are highly satisfactory. The pupils learn the method readily; they are not confused by the multiplicity of cases; they retain the method more easily, and consequently need less drill. Best of all, the tendency to avoid mental checking of factors is reduced to a minimum.

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The average school graduate has a vague notion that 70% is passing, and may take years to learn that in adding a column of figures the passing mark is 100%, and is making a bill of material a mistake in the decimal point which costs \$10,000 is a pretty bad error.—David Cushman Coyle, *School Life*.

# SCIENCE AND ARITHMETIC IN THE ELEMENTARY SCHOOL CURRICULUM

WHIT BROGAN

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I am assuming the privilege of all speakers who are assigned a topic; namely, that of interpreting the title in such a way as to permit me to have my say unmolested by the programming committee. Hence you will hear very little about arithmetic as such because that subject has always seemed the basic science to me. It has lost its vitality because we have destroyed that position and made it a series of numerical abstractions.

My discussion today will be on science but do not forget that arithmetic is included in that term. The last reference to arithmetic will be to call your attention to the excellent statement of R. L. Morton and his committee in the November issue of the *Curriculum Journal*.

A healthy, curious small boy, until he has been squelched by school procedure, can tell us more about the place of science in an elementary school than can pedagogues. Instead of listening to me this afternoon you could get a better answer to the question implied in the title of this talk by listening to that boy pour forth a constant stream of "How," "Why," "When," or, "What makes it go?"; "How do you work that?" et cetera. Science, insofar as possible, should help him answer his questions, and that is its place in the elementary school curriculum.

Of course, that is a lovely generalization which will probably give rise to some hows, whens, and whys of its own. Nevertheless, I'll stick to that generalization as an adequate description of the place of science in an elementary school.

Science is a newcomer in the elementary curriculum family. Moreover this babe was born during a combination of a family quarrel and spring house cleaning in our pedagogical household. Father, mother, aunts, uncles and distant relatives, all have plans for the correct up-bringing of this newcomer and the plans do not harmonize. In addition, this babe seems to be the only male child in a somewhat effeminate group.

Actually, and seriously, the problem in science is exactly the same as it is for all other school subjects. Is science in the elementary school a body of material and a method with which

children answer their questions, or something that teachers teach, regardless of immediate questions but directed toward future needs? To put it as specifically as possible, should a teacher show a pupil how to repair household electric equipment, or have him go through standard experiments on fixed apparatus to teach laws in physics? Does Johnny bring his broken bicycle to the laboratory or does the teacher buy expensive machinery to demonstrate wheels, pulleys, leverage, et cetera? Or, to reduce it to the standard phraseology, is science a body of subject matter to be acquired in a systematic fashion, or is it a procedure whereby children secure an increasing ability to answer questions which bewilder them, repair machines they use and need, to secure an increasing control over their ordinary lives?

"Neither one exclusively but some of both" is the easiest answer but I doubt if it will work for the busy and hurried classroom teacher who already has her hands full. She will teach science as she teaches other material, be it by textbook, project, experience, or what have you. She will take care of this curriculum baby the same as she cares for the older members, no doubt wondering all the while when birth control will be exercised in the educational family.

So far I've merely presented the controversial issue, perhaps over elaborately, but because I want to give an opinion concerning science it seemed necessary. Maybe it is just the inevitable pedagogical prologue. Now for the opinions.

First, science is a method of inquiry, not a subject. Science, as is true of any method of inquiry, does not exist in a vacuum but in relationship to the material subjected to inquiry. Please, or as the children say, pretty please with sugar on it, do not take that one sentence to mean that I recommend an abstract, unrelated "method." There is no such animal. Scientific inquiry in various areas has given to us a tremendous body of subject matter of indubitable value. It is our duty as educators to help children acquire much of this information because they need it to live today. Yet it is a possible and frequent happening to see the results of scientific inquiry taught in such a manner as to kill any spirit of investigation on the part of the learner. And this in the name of science. We must realize that a pupil can acquire a large amount of knowledge given him by science, yet remain totally without scientific ability to deal with any problems on his own environment.

Just to avoid quibbling it may be necessary to add that a child who practices investigating, experimenting with, correcting and controlling the ordinary features of his life, will study, of necessity, the organized knowledge of science. But, the above statement is not reversible. Repeat that sentence three times daily.

Second, we must decide whether or not our primary concern in the elementary school is to be with the content or the method of science. This is not an "either or" question, but merely one of emphasis. It is proposed here mainly as a forerunner of the next point, but a few words of elaboration may help. This elaboration is going to take the form of a specific classroom situation.

Two second grade children ran in from a recess indulging in a heated "It does," "It doesn't," flurry. The "does" and "doesn't's" were over iron, does it sink or float in water? Teacher would know, hence must settle the question. She did very simply. There was an empty tin can on her desk, and after convincing the skeptical young minds that tin and iron were much alike she went with them to a wash basin, filled it with water and let the children see the can float. She then took a hammer, pounded the can into a lump of metal, and let them see it sink. She took another can, punched a hole in the bottom and let them watch it fill, then sink. She then told them about boats and why a steel ship floats. In other words, she gave them a complete and satisfactory answer to their questions, verbally and visually, without bothering to guide them through the process of discovering the answer for themselves. Was she right or wrong? I do not know, but will always feel it was one of the best jobs of incidental teaching that I've ever seen if one considers only the subject matter or knowledge side of the question.

Third, do we want children to develop inquiring minds, together with an emotional capacity to cope with the situations arising therefrom? Do not answer this one too fast.

Let us return to the first proposition, that science is a method of inquiry and add a corollary, that all phases of human life, mechanical, moral, political, religious, are legitimate fields of investigation. Elementary school children do not come into direct conflict with established patterns very often but are helpless and submissive. Nevertheless, circumstance is such that small children are becoming, increasingly, the emotional victims of a bewildered adult society.

The above sounds highbrow and theoretical when one is supposed to be considering science for elementary school children but it isn't. Almost any day now some obstreperous young soul is going to discover that not only are the habits of birds and bees and flowers and trees natural science but that human beings come under the same category. It has always seemed a strange paradox to me that we humans consider ourselves so much superior to animals, but when we want to teach our young natural science we have them study beasts lest they become contaminated by knowledge of the conduct of humans. Hence, I believe the average teacher, which is all of us, should understand rather clearly the consequences of any thorough-going science program that is concerned with inculcating the inquiring attitude of science into the pattern of childhood behavior. Our answers will be questioned, our right to give answers will be questioned, the basis of our assumed authority will be questioned. We will have to face the task of dealing with children emotionally and intellectually as opposed to the authoritarian basis of school control which now predominates and will be faced with the need of a teaching method based upon reasonable explanation instead of flat statement. Of course, all of this is extreme, but not at all improbable, and should represent the goal of teaching which is concerned with the method as well as the content of science.

However, there is another important matter we must consider which grows directly out of the points suggested in the preceding paragraphs, especially one question. If we guide children into the emotional and mental set of questioning and inquiring, how much of life is it "safe" to let them question? If the experimental technique is sound as a learning method, how far should the experimenting be permitted to go?

Children haven't acquired our knowledge of taboos and a priori truths. There are a number of "correct" answers which we know are correct "just because." For example, respectable teachers do not inquire into validity of our structure of property rights, nor doubt the soundness of our moral precepts in sex relationships. Young minds trained to inquire and not accept might not be so acquiescent. Do we want that? What about religion, the nature of patriotism, et cetera? Do not forget that all Socrates did was to ask questions about things respectable people were not supposed to question.

We all realize that science can be kept perfectly safe for

elementary school children. We can give them little electric outfits, cute little steam engines that whistle, and houses with glass fronts so we can peep in on the private lives of ants. We can go further and have a workshop where youngsters can repair simple machinery brought from home and learn how to work safely with electricity, leaves, and lizards. We can do all of this, and never let it penetrate the child's mind that science has any significance beyond a mechanical one. However, let's not deceive ourselves as to what we are doing. We are not teaching science, a method of inquiry and control, except as applied to mechanical objects. Perhaps that is enough. Probably we do not want humanity's actions exposed to the light of scientific inquiry or rational judgment. Obviously we do not want children to develop an emotional mind-set which leads them to believe custom is open to question. And I think we are wrong.

Suppose we became interested in helping children develop experimental attitudes and techniques in social matters, then how would we use science in the elementary curriculum? Briefly, we must let them experiment with the curriculum. Insofar as the school is concerned, the curriculum and its regulatory discipline is society for the child. Through the construction of that curriculum, by the nature of its attendant disciplines, we can contribute somewhat to teaching the child to analyze, evaluate, and control his social environment; or we can teach him to submit as graciously as possible to imposed learnings and autocratic control. As we are learning from world affairs, we must acknowledge that imposition and autocracy are the antithesis of science in human life, yet we continue these practices even in the teaching of science subject matter.

Why not guide children, even little ones, into establishing objectives of learning? Why not aid them as they conduct experiments with learning materials directed toward achieving these ends? Why not assist them in evaluating their objectives, the experiments directed toward achieving them, the results, and the construction of new and better objectives? Quite simply, it can be stated in one more question. Why not apply the rational, scientific method of action to all of the learning in the public schools? Or are we afraid of it?

The few preceding paragraphs are all questions which we must answer truthfully if we are concerned with real science in the curriculum; however, I want to give the closing moments to some suggestions for inquiry in an area which is sometimes over-

looked in a discussion of curriculum; namely, the knowledge and the attitudes of teachers. These two items are, in my opinion, the heart of any curriculum despite the voluminous tomes turned out by curriculum experts.

This discussion is centered around science in the curriculum. Supposedly we are all interested in it as a source of real value in learning. What does science mean to us as adults in society, as teachers in society? What is our concept of science as a method of inquiry, as a guide to social action?

What we teach children in science is entirely dependent upon what we believe. An obvious truism, but a neglected one. Yet, I'm becoming worried about the attitude which says we human beings can conquer the physical world scientifically but must depend upon dogma, superstition, and a reverence based on repetition, to direct our usage of mechanical power.

The last election is a good illustration of this point, and I shall try to elaborate it. (By the way do not take this as a plea either for or against Roosevelt.) The present administration has done something which had never been done before in this country. It has furnished us with information out of which we can frame intelligent questions concerning the direction of our national future. The National Resources Board in its reports is outlining clearly our potentialities and our problems. This material is startling in its revelations and to anyone who will think, a source of enlightenment. Despite that fact, this last election showed a distinct trend back toward the mumbo-jumbo which produces starvation in the midst of such plenty that one of our chief concerns is limitation of food production. A bunch of monkeys in a cocoanut tree would have more sense than to starve because there were too many cocoanuts.

Someone may ask,—“What business is this of a science teacher? We are interested in chemistry, physics, zoology, natural science, et cetera. You are talking about sociology and things like that.” No, I'm talking about science, a method of intellectual inquiry in the field where it is most needed, human relationships. I'm also talking about the responsibility of science teachers for training children to become accustomed to such methods of thought and action. Scientists, above all persons, must realize that increased mechanical efficiency directed toward achieving barbaric goals is not progress, but merely animal cunning raised to a higher level. On the other hand, the use of old tools to more humane ends is progress.

Germany, today, is a perfect example of mechanical science dominated by brutish superstition. However, we do not need to cross the ocean to find our examples. On Monday evening, Nov. 14th, Dorothy Thompson gave a brilliantly bitter speech concerning the persecution of 500,000 Jews under the control of Naziism. She did not mention the 2,000,000 sharecroppers living under very near the same conditions here because of our superstitious faith in capitalism. Walter Lippmann once observed in a bitter attack on Fascism, . . . "that if Democracy loses one election, there will be no more elections," but his columns are just as bitter against workers in this country who presume to fight for a right to vote on conditions of employment and wages.

What has all this to do with science? Do you suppose a person accustomed to scientific thinking would be guilty of the above inconsistencies? Perhaps, but let us hope not. We cannot go on much longer creating twentieth century engines to appease the appetites and sooth the gods of cavemen.

Lancelot Hogben, the noted English scientist, has stated simply and clearly the function of science as a social instrument. After discussing many of the beliefs which hindered progress he wrote:<sup>1</sup>

"In their place modern science now offers us a new social contract. The social contract of scientific humanism is the recognition that the sufficient basis for rational cooperation between citizens is scientific investigation of the common needs of mankind, a scientific inventory of resources available for satisfying them, and a realistic survey of how modern social institutions contribute to or militate against the use of such resources for the satisfaction of fundamental human needs. The new social contract demands a new orientation in educational values and new qualifications for civic responsibilities—the power to shape the future course of events so as to extend the benefits of advancing scientific knowledge for the satisfaction of common human needs, guided by an understanding of the impact of science on human society."

In this statement is the true charter for science teachers,—a description of their responsibility for liberating us from superstition into the freedom to enjoy the fruits of our achievements.

<sup>1</sup> Hogben Lancelot, Scientific Humanism, *The Nation*, Nov. 12, 1938.

## MEMORY DEVICES FOR SCIENCE AND MATHEMATICS

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Science and mathematics present to the pupil many associations which are confusing, many concepts which are difficult to understand. It is the delight of the efficient teacher to devise and use methods which will enable the pupil to surmount these difficulties. Perhaps it is trite to point out that memory devices may be used to aid in forming proper associations; that familiar facts, aptly applied as illustrations, may make usually hazy concepts understandable. Yet many teachers fail to realize the full effectiveness of even crude devices and of analogies which are not necessarily scientifically accurate. Such aids will serve a beneficial and possibly a lasting purpose if they appeal to the student's imagination or if they can give a new and perhaps startling meaning to some very familiar thought.

The value of such devices was impressed upon the writer, some fourteen years ago, while still in high school. The twelfth grade trigonometry class was having difficulty with those signs  $<$  and  $>$ . "Just remember" said Isaac M. Devoe, one of the most human of mathematics teachers, "that you always open your mouth toward the biggest piece of pie!" Those signs,  $<$  and  $>$ , certainly do look like open, hungry mouths. Can one possibly forget, after such an illustration, that the statement " $x > a$ " means that  $x$  really is greater than  $a$ ?

Many geography teachers use an almost equally effective device for helping the student differentiate between those twin demons "latitude" and "longitude." On most of the maps drawn prior to about 1500 A.D. the earth was depicted either as an elongated ellipse, a sector, or a rectangle. One feature common to all such maps is that the earth appears longer east and west than it does north and south. So the student can easily remember that "Longitude" means the "Long way" on the old maps. Easy enough then, to realize that "longitude" applies to east and west measurements.

Another effective device is the use of blotting paper as a means of introducing the concept of relative humidity. Perhaps the slight scientific inaccuracy in the demonstration is more than compensated for by the ease with which it enables the novice in science to visualize an otherwise vague abstraction.

After presenting the usual demonstrations of evaporating alcohol from a thermometer bulb, carbon tetrachloride from the finger-tip, etc., the way is easily paved for a presentation of relative humidity by dropping a piece of blotting paper into a beaker of water. After a short while ask the class if it probably could soak up any more water. "No." "Then it must contain, right now, what per cent of all the water which it can hold?" "100%." "And if we were to squeeze out half of the water, then its water content—or relative humidity—would be what per cent?" "50%." Thus it is easy to develop the thought of relative humidity of the blotter. This can then be easily extended to relative humidity of the air. That the air is somewhat similar in action to blotting paper can be made apparent by spilling two small and approximately equal amounts of water on the desk, removing one with blotting paper and "blotting" the other with air—that is, letting it evaporate.

The scientific study of weather brings up still another memory bugbear. Cyclones and anticyclones must be associated with their proper directions of rotation. This association is usually very confused and uncertain in the mind of the student, whether it be based purely on memory, or on the supposedly scientific reasoning relative to the direction of the earth's rotation. This uncertainty and confusion may be definitely eliminated if we make use of the letters C.C.C. and A.C. Most junior high students have certain associations for these letter groups. They may not know definitely that "C.C.C." means "Civilian Conservation Corps"—but they are all familiar with the letters and use them glibly enough. Similarly they may not know that "A.C." means "alternating current"—but nearly all of them do know that it means something. Sufficient for memory purposes that they are already familiar with these letter groups. After understanding the meaning of the terms "cyclone" and "anticyclone," of "clockwise" and "counter-clockwise," they need only once the suggestion that, since (in the Northern Hemisphere) cyclones rotate counter-clockwise we can easily remember "C.C.C." (Cyclones Counter-Clockwise). Anticyclones, rotating clockwise, can be recalled by "A.C." (Anticyclones Clockwise).

Some teachers may tend to scorn as artificial these devices, but experience seems definitely to indicate their value. Many others might be described, but these samples serve to indicate a type of memory device much appreciated by the students. Being constantly on the alert for opportunities to use such devices will often result in their development as needed.

## THE FACTORS DETERMINING LIQUID PRESSURE

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**PROBLEM:** To study the effect of the depth and the density of a liquid, on the pressure exerted by that liquid.

**APPARATUS:** Glass tubing, mercury, rubber tubing, supports, clamps, meter sticks or metric scales, alcohol, kerosene or  $\text{CCl}_4$ .

**ILLUSTRATION:**

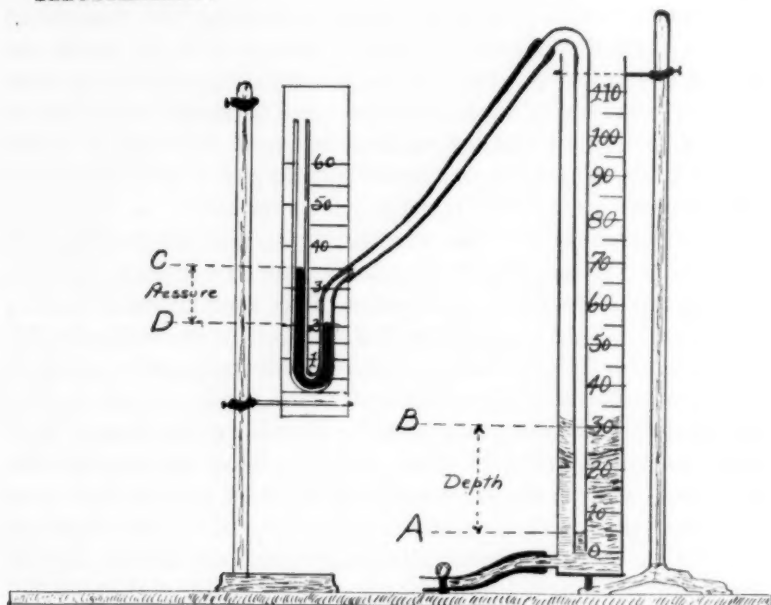


FIG. 1

**NOTE:** Fluid pressures of moderate strength are conveniently measured by a device called a mercury manometer. In this, the pressure is read or expressed in terms of "centimeters of mercury" which units can easily be converted into grams per square centimeter.

### METHOD

**PART I:** Using medium heavy walled glass tubing form a J-shaped manometer tube and attach it securely to a metric scale as in Fig. 1. Fill the manometer tube  $\frac{3}{4}$  full of mercury. Set up a glass tube or cylinder about 4 cm. in diameter and about 120 cm. long and arrange it so that it may be filled with water as in the illustration. At one end of a piece of glass tubing about 120 cm. long, form a J-shaped bend and place the long end in the cylinder. Connect the short end to the manometer tube by

means of a piece of heavy walled rubber tubing as in the illustration. It is imperative that the joints be air-tight.

As the liquid is poured or let into the cylinder it presses against the air in the *J* tube and this pressure is transmitted to the mercury in the manometer tube where it can be measured and recorded as centimeters of mercury.

From the illustration it is seen that four readings are necessary for each trial, namely, points *A*, *B*, *C*, and *D*. Now *C-D* indicates the pressure in cm. of mercury and *B-A* represents depth in centimeters of whatever liquid is used. Take the readings at *A*, *B*, *C*, and *D* and record. This is the zero reading and since there is no water present there should be no pressure.

Allow water to enter the tube until *B-A* equals 10 cm. Then take the readings at the four points and record in the data under the column marked Part I. Continue this procedure adding 10 cm. at a time until ten readings have been taken. Complete the computation called for in the data.

On a sheet of graph paper, plot the values of pressure on one axis and the values of depth on the other axis. Connect the points. What figure is produced?

PART II: Repeat the experiment using alcohol,  $\text{CCl}_4$  or kerosene in the place of the water and record in the data under the columns marked Part II.

On the same graph paper used in Part I, plot the values obtained in the alcohol determination using colored pencil. Compare the two figures.

DATA						
PART I				PART II		
Trial	Readings				Depth	Pressure
	A	B	C	D		
0						
1						
2						
Etc.						

#### QUESTIONS:

1. What is the effect of the depth on the pressure?
2. What is the effect of the density on the pressure?
3. What can you tell of the density of mercury from this exercise?

## DEMONSTRATIONS DEALING WITH PHOTOSYNTHESIS\*

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In the teaching of photosynthesis, it is desirable to demonstrate that in sunlight a plant absorbs  $\text{CO}_2$  but that in the dark, this does not occur. A method usually employed is to grow a potted plant in a sealed container in which a vessel containing  $\text{Ca}(\text{OH})_2$  has been placed. Presumably, the  $\text{Ca}(\text{OH})_2$  reacts with the  $\text{CO}_2$  and the plant deprived of  $\text{CO}_2$  in this manner is supposed to show the ill effects of such treatment. This technique is not only tedious and unwieldy but in many cases fails to accomplish its purpose. Usually, the plant survives for a considerable length of time and the evidence does not permit a ready conclusion.

A titration method has been adapted to demonstrate this absorption of  $\text{CO}_2$ . H. Munro Fox, in England, used this with respect to *Elodea*. The Committee on Techniques has modified and added to this technique in the following manner.

Five to ten cc. of a .1% solution of Brom Thymol Blue in tap water are added to fifty cc. of aquarium water in which *Elodea* has been growing. Brom Thymol Blue is blue in alkali and yellow-green in acid; if it is not blue when dissolved in tap water, one drop or so of a very dilute  $\text{NaOH}$  (e.g., .1 N) will turn it that color. In any case, the Brom Thymol Blue—aquarium water mixture should be blue before use.

In the demonstration before the class, two large test tubes are filled with the blue fluid. Both are turned yellow-green by blowing in  $\text{CO}_2$  either from a generator or from the lungs. The class may be asked to suggest a method whereby the solution may be turned back to blue. In every class in which this demonstration has been attempted (30 or more classes by different teachers) several students suggest that this may be done by removing the  $\text{CO}_2$ . Eventually, upon further questioning, someone suggests that heating the tube will drive off the  $\text{CO}_2$ . A small amount of the green-yellow  $\text{CO}_2$  saturated liquid is heated in a test tube. As the gas is driven off, the liquid turns from yellow-green to blue.

\* The Committee on Techniques of the N. Y. Biology Teachers Association consists of the following:—D. Bauman, M. Bleifeld, P. F. Brandwein, Chairman, I. Halpern, S. Katz, M. Rabinowitz, G. Robinson, G. Schwartz, Secretary, H. Scott, D. Sigoda, B. Wigler and R. Zinman.

After this, two thriving sprigs of *Elodea*, each having an end bud are placed in one of the test tubes. Both are stoppered and compared. The students clearly see that both are yellow-green and that one tube differs from the other, merely in that it contains the two sprigs of *Elodea*. In bright sunlight, the tube containing the *Elodea* turns blue within 15 minutes, demonstrating that the  $\text{CO}_2$  is used by the plant. The control remains yellow. In medium light or direct artificial light from a bulb about one and one-half feet away from the plant, it takes from 20 to 40 minutes for the change to occur. This depends, of course, on the intensity of the light. Oxygen, bubbled through the control, does not change the color. (This last procedure is not really necessary since it has been demonstrated that removing the  $\text{CO}_2$  changes the color from yellow-green to blue. However, it may be added to convince any skeptics.)

This technique may be used to show that in the dark  $\text{CO}_2$  is not absorbed. If two other tubes, treated as mentioned (e.g. one with *Elodea*, one without) are placed in the dark, the *Elodea* tube does not change color. Both tubes remain yellow-green, demonstrating that the  $\text{CO}_2$  is not absorbed (as compared with those in light.)

In addition this technique may be used to show that a plant gives off  $\text{CO}_2$  in the dark. When the *Elodea* has turned the indicator blue, the tube containing it may be placed in the dark. The control for this is a tube containing the blue indicator, minus the plants. The  $\text{CO}_2$  produced by the *Elodea* turns the indicator back to yellow. The control remains blue.

Phenol red may be substituted for the Brom Thymol Blue. In this case, the change is from yellow to deep pink or red as the  $\text{CO}_2$  is used up.

It is advisable to use as little indicator as possible. In many cases only one or two cc. are sufficient to turn the aquarium water blue. The experiment will be finished more quickly if one blows in  $\text{CO}_2$  just sufficient to turn the indicator from blue to yellow-green.

The advantages are obvious, the most important ones being that the students see what is happening in one period, and that they are stimulated to thinking if they are asked to explain the changes in color. Secondly, the method is inexpensive, easily set up and simple with regard to the apparatus used. In no case, where this has been used in class, have the changes in color been confusing to the students.

## TWO YEARS WITH CHEMISTRY PROJECTS

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The project method, while presenting many undesirable features if over-used, offers one of the richest sources of stimulation that can be found for second semester chemistry. Twenty-four weeks of basic instruction, followed by six weeks of project work affords variety, offers a real challenge to the student, and provides one of the richest periods of the entire course.

Interest and anticipation may well be stimulated by "talking it up" over an extended period beforehand. Mention may be made of what is to come several weeks in advance, in order that students may be considering possible projects as they pursue the work of the regular course.

At the beginning of the appointed six-week period, a list of some fifty or more good projects may be posted, with just enough description of each to offer "leads." Care should be taken in posting this list, as too many from which to choose may lead to some confusion. More important, however, is the "workability" of each. For instance, if steam pressure is needed to prepare wood pulp for paper-making, and your laboratory is not equipped for that, then the student should not be permitted to enter upon such a project. Don't attempt to solve the student's problems for him, however. Guide him so that he will not waste time on the beginning of a job he can never finish.

A general plan of procedure should be drawn up for all to follow. The system presented here has been found to work satisfactorily:

1. Selection of project (list three choices, indicating first choice)
2. Conference
3. Location of reference sources
4. "Definitization"
5. "Reading up"
6. Outline of procedure
7. Conference
8. Experimental work
9. Recording and write-up
10. Class report

With the exception of number four, the points of procedure are self-explanatory. A student soon finds that the general field in which he intends to work is much too large for him. It is

necessary to limit that field to certain specific phases. That is what is meant by "definitization."

Dates should be set for completion of the first seven points, so all will be prepared to begin laboratory work at the same time. It is well to insist also on a complete (tentative) plan of procedure before any laboratory work is begun, as needless waste of time may thus be easily avoided.

All students (or groups, if cooperative projects are undertaken) should list all chemicals and apparatus needed for their projects, which they do not already have in their possession. The list may then be compiled by one of the students, and the materials collected together in a case easily accessible from the laboratory. This will take the big share of strain off the instructor when laboratory work is begun. Students should be kept out of the regular supply shelves, anyway, though access to shelves containing what they need is desirable. Failure to observe this point results in a rush on the instructor which can be anything but pleasant.

Nearly a week should be spent in preparing for the laboratory work. During this time, while a good deal of the work of reading-up must be done outside of class, review of the important sections of the text may well be made. A thorough review covering methods of preparation, tests for various ions, and calculations, is about as painless at this time as it can be made, for the student is reviewing for actual use. General laboratory directions should be given at this time, too. Everyone should be required to record results at the time they occur in the laboratory. Care should be taken to make the student realize that inaccuracy is the unforgivable sin in science.

Occasionally it may be desirable to vary the straight laboratory work by having a day in the class room. Such days may well be "interest periods"—i.e., a day on dope and drugs, or a day on common names of chemical products.

As projects are finished they should be written up for presentation before the class. Occasionally it may be necessary to have a student work with more than one project, if his selection can be completed in a short time. As the projects are finished the class should be assembled for the purpose of hearing the reports. Discussion of the project should be encouraged, with the reporting student leading, and answering the questions that arise. All students should be urged to take notes on each report, in order that he might benefit by each project.

An exam taken from the reports serves well to wind up the project period, and also, if announced early, encourages worthwhile note taking.

Emphasis should be placed early upon the fact that negative results are just as valuable as positive ones. Those who fail to get good results from their laboratory work should be reminded of the countless experiments of Thomas Edison in developing the electric light. No one should be deprived of the experience of feeling at least a measure of success.

In the event that students finish up irregularly, those through first may be given special laboratory experiments to do, from their laboratory manuals. Or a series of unknowns may be given out for identification. The resourceful instructor will find little difficulty in caring for "irregulars."

If a display case can be built up from the results of the project work, giving credit to the students whose works appear, still greater interest results.

Properly conducted, six weeks of project work can be the most enjoyable period of the term, for teacher and student alike. Breadth of reading in the field of chemistry, exercise of originality and application of initiative, as well as learning through actual contact, are a few of the many desirable features of well executed project work.

From the teaching end alone, the plan is justifiable. A group of students interested in their work because it is vital to them, repay the efforts of the instructor many-fold. The gratification incident upon having a large share of the class asking for extra time in the laboratory, and prepared to make the most of that time, is worth experiencing.

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#### KAPPA DELTA PI

The annual dinner of Kappa Delta Pi will be held at the Hotel Cleveland, Cleveland, Ohio, Tuesday, February 28, 1939, 6:30 P.M.

Dr. Edward Lee Thorndike will speak on the subject, "Education as Cause and as Symptom."

Because of the significance of this address, the Society is opening this meeting to non-members of Kappa Delta Pi as well as members, and a general invitation is extended to any who attend the sessions of the American Association of School Administrators and its various sections or the allied meetings.

Tickets for the dinner are now on sale at \$1.75 each. Reservations should be made as soon as possible. Remittance should be sent to Professor E. I. F. Williams, Heidelberg College, Tiffin, Ohio.

## EASTERN ASSOCIATION OF PHYSICS TEACHERS

One Hundred Fortieth Meeting

ROXBURY LATIN SCHOOL

West Roxbury, Mass.

Saturday, December 3, 1938

### PROGRAM

- 9:50 Meeting of Executive Committee.  
10:10 Report of the Secretary.  
10:20 Report of the New Apparatus Committee.  
Mr. Hollis D. Hatch, Chairman.  
10:50 Report of the New Books and Magazine Literature Committee.  
Mr. Richard Porter-Boyer, Chairman.  
11:05 Address: "Physical Sciences Course—Its Justification and Sequence."  
Mr. John C. Hogg, Head of Science Department, Phillips Exeter Academy.  
12:00 Address: "What the College Expects of an Elementary Course in Physics."  
Dr. John C. Slater, Head of Physics Department, Massachusetts Institute of Technology.  
1:00 Luncheon, and Social Hour.  
2:30 Greetings: Mr. George N. Northrop, Headmaster Roxbury Latin School.  
2:45 Address: Dr. Harlow Shapely, Director Harvard College Observatory.

Members of the Association are invited to be the guests of the Roxbury Latin School for luncheon. Please return the enclosed card before December first.

To reach the Roxbury Latin School by Electric from Boston: Take a subway train at Washington Street station to Forest Hills Elevated station. Transfer at Forest Hills to a Charles River car, and leave the car at Saint Theresa Avenue. The School building is of brick, and in plain view from this stop.

To reach the Roxbury Latin School by auto from Boston: Go southward on auto route No. 1 to a point apposite the Arnold Arboretum where the road forks. At this fork route No. 1 bears right on Brook Farm Parkway, while Center Street continues straight ahead. There is a stop light at this fork. Continue straight ahead on Center Street through the business section of West Roxbury to Saint Theresa Avenue and turn left. There is a large stone church on the corner. The school building is of brick.

### OFFICERS

President, Ralph H. Houser, Roxbury Latin School, West Roxbury, Mass.

Vice-President, John P. Brennan, High School, Somerville, Mass.

Secretary, Carl W. Staples, High School, Chelsea, Mass.

Treasurer, Preston W. Smith, 208 Harvard St., Dorchester, Mass.

### COMMITTEES

*Executive Committee.*

John C. Gray, Phillips Andover Academy.

Lawrence A. Howard, East Boston High School.  
Charles S. Lewis, Brighton High School.

#### *New Books and Magazine Literature*

Richard Porter-Boyer, High School, Newtonville, Mass.  
Floyd E. Somerville, High School, Newtonville, Mass.  
George W. Seaburg, Hyde Park High School, Boston, Mass.

#### *New Apparatus*

Hollis D. Hatch, English High School, Boston, Mass.  
Temple C. Patton, Worcester Academy, Worcester, Mass.  
Dr. Andrew Longacre, Phillips Exeter Academy, Exeter, N. H.

### BUSINESS MEETING

The following were elected to active membership: Mr. George A. Buckle, Jr., Somerset High School, Somerset, Mass.

Mr. Warren P. Leonard, Wilbraham Academy, Wilbraham, Mass. Mr. Chester F. Protheroe, Beaver Country Day School, Chestnut Hill, Mass., was elected an associate member.

A letter from Dr. Glenn W. Warner, Editor of *SCHOOL SCIENCE AND MATHEMATICS*, regarding a list of books on Physics which is being compiled, was read. The letter invited members of the Eastern Association of Physics Teachers to aid in the preparation of the final list. Mr. LeSourd spoke briefly, stating that the list is to be printed in *SCHOOL SCIENCE AND MATHEMATICS*. The matter was referred to the Committee on New Books and Magazine Literature, and any other members interested were invited to participate. Those interested may obtain preliminary lists from the editor of *The American Physics Teacher*, Pupin Physical Laboratories, Columbia University, New York. Additions to or subtractions from the list should be submitted to the editor.

### REPORT OF NEW APPARATUS COMMITTEE

MR. HOLLIS D. HATCH, *Chairman*.

The apparatus committee (Mr. H. D. Hatch Chmn.) reported as follows:

(Mr. Patton's report)

(Dr. Longacre's report)

(Mr. Drury's report)

Mr. Hatch showed two electrodes of stainless steel of particularly simple and substantial design. They are about three-fourths iron yet do not replace copper from blue vitriol solution nor are they attracted by a magnet. When placed in a copper sulphate solution and connected to a four or six volt battery, copper is deposited on the cathode. Reversing the polarity of the battery transfers the copper to the new cathode. The deposit may be removed with dilute nitric acid or sandpaper. A copper electrode of similar design is used to illustrate electroplating.

Two stainless steel electrodes shaped for use with test tubes illustrated electrolysis giving hydrogen and oxygen. What electrolyte to use proved quite a problem; some gave considerable foam, some attacked the steel, and most gave less than half as much oxygen as hydrogen. The best Mr. Hatch has so far found is potassium sulphate, with a ten volt EMF. If anyone finds a better electrolyte please let him know at English High School, Boston, Mass.

## REPORT ON NEW TYPE BOYLE'S LAW APPARATUS

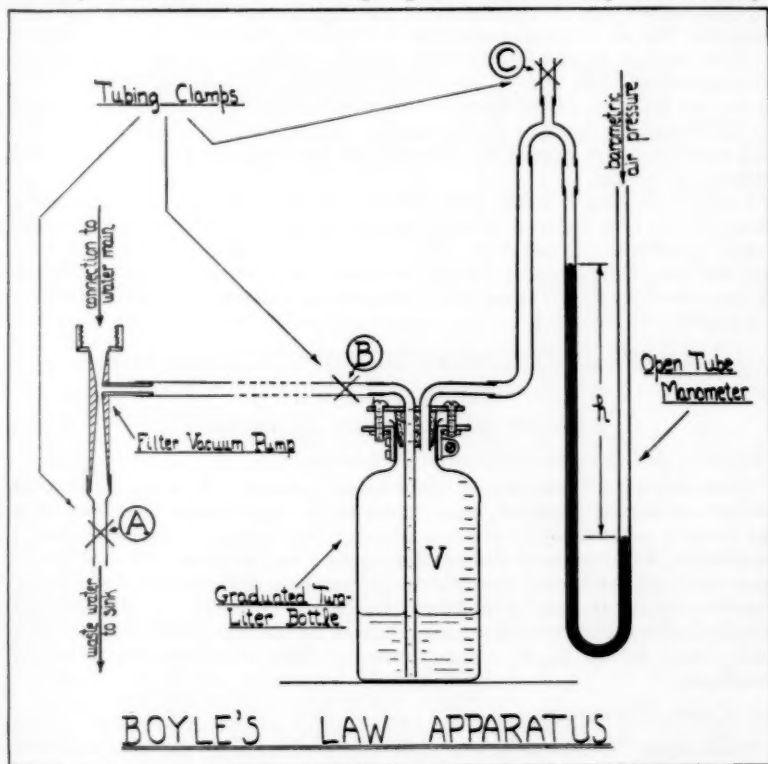
TEMPLE C. PATTON, *Worcester Academy, Worcester, Mass.*

In an article entitled "A New Method in Teaching Physics," (by H. N. Scott, *SCHOOL SCIENCE AND MATHEMATICS*, November, 1937 issue) the author makes a strong plea for bigger and easier-to-see pieces of lecture apparatus. In this article he backs up his argument by good common sense and describes several large-scale devices which he has used and which he finds at once inexpensive, impressive and instructive.

The present apparatus before you is another such large-scale apparatus. It is designed to demonstrate Boyle's Law. I think you will agree that it is inexpensive, and I hope you find it instructive.

Most Boyle's Law apparatuses are small-scale affairs using a small volume of air to work on, this volume usually confined by small bore tubing and mercury surfaces. In the present device a man-sized volume of air is used, a volume which fills the upper half, or more if desired, of a two-liter bottle.

To compress such a volume of air using mercury would be both expensive and difficult. Hence it was decided to compress air by the use of water under pressure, a method both inexpensive and, as I will show, relatively simple. Of course, the use of water introduces a complication in as much as the volume of air will be saturated with water vapor. However, this factor can be corrected for, or if an approximate demonstration is all that is desired, the effect of the water vapor pressure can be neglected entirely.



By a rather unusual way of making a connection from the bottle to the water faucet, it is also possible to have the volume of air in the bottle subjected to both pressures above and below normal atmospheric pressure. By connecting the bottle containing the confined air to an old type filter vacuum pump (or new type with check valve removed), as noted on the diagram, and attaching a rubber tubing with a tubing clamp to the bottom part of the filter pump, water can either be forced into the bottle (when clamp A is closed) or pumped out of the bottle (when clamp A is opened). In the first case the air is compressed, in the second case a partial vacuum is produced. The clamp B serves to hold the air under any pressure condition once the condition has been obtained.

The two liter bottle was calibrated in less than an hour. It was marked off in 100 cm.<sup>3</sup> graduations using India ink on white paint.

Before demonstrating the apparatus I want to point out the simple way in which the rubber stopper is held tightly in the mouth of the bottle. By the use of two angle irons, a water hose clamp, a piece of strap iron, and two bolts, there is possible a device which fits outside the neck of the bottle and which firmly holds the stopper in the bottle mouth against any pressure which might act to blow it out. The diagram serves to show how the stopper-holder is assembled.

I will now make a run with the apparatus. Clamp C is first opened and a desired volume of air is introduced into the bottle under atmospheric conditions. The clamp C is then tightly closed for the remainder of the experiment and the entrapped air is thus tightly confined also. I will now compress the air to smaller volumes by opening clamp B, shutting clamp A, and turning on the faucet very slightly. Readings of the volume and corresponding open tube manometer are taken at several compression pressures. Following this, clamp A is opened and the water faucet is turned on full force. This pumps the water out. Again readings of the air volume and corresponding open tube manometer readings are taken for several vacuum pressures.

I also have here a water thermometer which I think you might enjoy seeing. Note how the graduations reverse around 4°C. Note also that the lowest graduation is not 4°C. This fact serves to show the student that rise and fall of the liquid in a liquid-in-glass thermometer is not due to the expansion of the liquid alone, but rather to the *unequal* expansion between the liquid and the glass.

### THREE INEXPENSIVE DEMONSTRATION AIDS

MR. W. S. DRURY,

Middlesex School, Concord, Massachusetts

#### "Bimetal" for Showing Differential Expansion:

Thermostatic "Bimetal," a commercial product of brass and invar welded or brazed together, was shown to be much more sensitive than the familiar riveted strips of brass and steel for demonstrating differential expansion. A thin strip of it when held over a match flame will curl nearly back on itself, and even the thicker forms show deformations which are plainly visible. It can be obtained in sheets or strips, or shaped into spirals, helixes, U's and other forms, and in thicknesses from .005" to 0.1", and is made by the W. M. Chace Company, 1600 Beard Avenue, Detroit, Michigan.

#### For Visible Markings:

"Gift Wrap" Scotch cellulose tape was recommended for the quick and distinctive marking of glassware and apparatus. It sticks without wetting

and pulls off clean, and its brilliant shiny colors can be seen from a great distance. Many stationery and dime stores carry it in quarter- and half-inch widths.

#### *Glass Cubes Have Uses:*

Glass imitation ice-cubes, available at various Woolworth stores, can be used in the study of liquid pressure to represent cubes of water piled one on top of the other. They serve also as small density samples, and are interesting for showing strain patterns with polarized light.

### CENTER OF GRAVITY APPARATUS

Mr. Clark demonstrated a large scale apparatus as a substitute for the double cone and plane apparatus. It consisted of an inclined plane about 40 inches long and 5 inches wide, on which was placed a wooden disc of about twelve inches diameter, and a thickness of 3 inches, weighted eccentrically. When placed on the plane the disc rolls up and down alternately as the center of gravity falls and rises.

Dr. Andrew Longacre demonstrated a model intended to show the inside of a molecule. It gives three dimensional visualization of the arrangement of atoms in crystals, and the closest packing of spheres.

The model is constructed of ping pong balls cemented together with celluloid cement and so constructed with pegs that each layer can be removed from the others to show the arrangement.

### REPORT OF COMMITTEE ON NEW BOOKS AND MAGAZINE LITERATURE

MR. RICHARD P. BOYER, *Chairman, Newton High School*

MR. FLOYD E. SOMERVILLE, *Newton High School*

MR. GEORGE W. SEABURG, *Hyde Park High School*

#### NEW BOOKS

*The Fine Structure of Matter*, Clark, C. H. D., Sept. '38. 252 pp. \$4.25.

Wiley. Crystal structure, polarization, line, spectra. This book is part 1 of vol. 2 of *A Comprehensive Treatise on Atomic and Molecular Structure*.

*The Serial Universe*, Dunne, J. W., Sept. '38. 240 pp. \$2.00. Macmillan.

An unusual treatment of relation to time, past and future. Refer also to previous book by same author—*An Experiment with Time*, which is now further explained.

*On Understanding Physics*, Watson, W. H., Oct. '38. 146 pp. \$2.25. Macmillan. A clear presentation.

*Mechanics, Molecular Physics, Heat, and Sound*, Millikan, R. A. et al., May '38. 498 pp. \$4.00. Ginn. Maintains the high quality of previous works.

*Glossary of Physics*, Weld, L. D. ed., May '38. 255 pp. \$2.50. McGraw. Defines 2,000–3,000 terms used in physics, and some of their sources.

*The Evolution of Physics*, Einstein, A., and Infeld, L., May '38. 319 pp. \$2.50. Simon and Schuster. The growth of ideas from early concepts to relativity and quanta.

*An Elementary Survey of Modern Physics*, Hull, G. F. 457 pp. \$3.50. Macmillan. Suitable for 2nd year college.

*Atoms, Men, and Stars*, Rusk, R. D., 298 pp. \$3.00. Knopf; \$3.50. Ryerson Press. "One of the finest examples of Science for the Layman." "Another rehash of left-over morsels of relativity, cosmic rays, radio-activ-

ity, and stellar mechanics, with perhaps an opportunity to wash the whole thing down with heavy water. The originality and ingeniousness of the writer raise all 17 chapters above the mediocre to a place among the stellar pieces of science reporting for the year."

*Physics of Electron Tubes*, Koller, L. R. 234 pp. \$3.00. McGraw.

*Contributions from the Physical Laboratories of Harvard University for the Year 1936*. Lea. \$4.00. pub. '38. Harvard University Press.

*Flame*, Ellis, O. C. and Kirkby, W. A. 136 pp. \$1.35. Complete physics of flame.

*Famous Men of Science*, Bolten, Sarah K. 376 pp. \$2.15. 16th printing of book first published in 1889.

*The Lightning Discharge*, Schonland, B. F. J. 19 pp. 75¢. Oxford Univ. Press. The nature of lightning—Halley lecture of Oxford University.

*Modern Plastics, Catalogue, Directory*, Oct. '38. 304 pp. \$2.00. Modern Plastics. Sources of plastic products and the properties of these plastics.

*Minerals Yearbook for 1938*. Review of 1937. U. S. Dept. of Interior. Oct. '38. 1339 pp. \$2.00. Gov't. Printing Office. Statistical information regarding every kind of mineral product found beneath American soil.

*The Leica Book in Color*, Baumann, A. F. et al. Oct. '38. 56 pp. 72 color plates. \$4.50. Westerman. Brief text 15 min. of theory. Information regarding new color film and making prints from your transparencies.

*Edison's Open Door*, Tate, A. O. \$3.00. Dutton. The life story of Thos. A. Edison.

*The Sun, its Phenomena, and Physical Features*, Abetti, Giorgis. Sept. '38. 360 pp. \$5.00. Van Nostrand. Physics of the sun, to date. Translated from the Italian.

*Science for the Citizen*, Hogben, L. 1082 pp. Knopf. Encyclopedic survey of the sciences.

Note: In addition to the above, there is a long list of books in the Fall Book Number of *Science News Letter*, the issue of Oct. 22, '38.

#### MAGAZINE LITERATURE

##### *Science Digest*

##### May 1938

- |                                               |         |
|-----------------------------------------------|---------|
| 1. "The Newly Discovered Elements"            | Page 14 |
| 2. "The Grand Coulee Dam"                     | Page 19 |
| a) A good source for Physics Problems         |         |
| 3. "A New Era in Heating & Air Conditioning?" | Page 32 |
| a) Based on experiments                       |         |
| 4. "The Flow of Electricity"                  | Page 52 |
| a) Review of old Theories                     |         |
| b) A new Theory                               |         |
| 5. "The Milky Way & Beyond"                   | Page 68 |
| a) Distance of galaxies                       |         |
| b) By Sir Arthur Eddington                    |         |
| 6. "Million Volt X-rays"                      | Page 83 |

##### June 1938

- |                                       |         |
|---------------------------------------|---------|
| 1. "The Electric Eel—A Living Dynamo" | Page 7  |
| a) Department of Physics, N. Y. U.    |         |
| 2. "Probing the Earth's Interior"     | Page 13 |
| a) From Laboratories of M. I. T.      |         |
| 3. "The Truth About the New Big Star" |         |
| a) Director of Yerkes Observatory     |         |

4. "Planes in the Stratosphere"	Page 33
a) Igor Sikorsky	
b) Possibilities of high speed travel	
5. "Making Synthetic Diamonds"	
a) McPherson College	
August 1938	
1. "Sunspots and Cosmic Rays"	Page 11
a) Carnegie Institution	
2. "The Electron Tube in Overalls"	Page 20
a) Applications	
3. "The Approach to Absolute Zero"	Page 38
4. "Tiny Particles in the Air"	Page 69
a) Carnegie Institution	
5. "The Ifs in Television"	Page 73
6. "Copernicus—Founder of Modern Astronomy"	Page 83
October 1938	
1. "Inaudible Sound"	Page 11
2. "The Basis of Scientific Belief"	
3. "Our Atmospheric Roof"	
a) Composition	
b) Astronomical Observations	Page 55
4. "Life on Other Planets?"	Page 66
a) Physical Conditions	
November 1938	
1. "The Earth Slows Down"	Page 8
a) Smithsonian Institution	
2. "Seeing Smaller"	Page 26
a) Introducing electronic lenses	
3. "What is Gravitation?"	Page 62
4. "Faraday—Pioneer of Electricity"	Page 91
December 1938	
1. "The Mirage Explained"	Page 45
2. "The Nature of Cosmic Rays"	Page 55
3. "Sir Isaac Newton"	Page 91
<i>Scientific America</i>	
May 1938	
1. "Number One Rocket Man"	Page 270
a) Pioneering in rocket flight	
2. "Unpuzzling Color"	Page 284
a) A new system	
June 1938	
1. "Personalities of the Elements"	Page 340
a) Explanation of properties	
July 1938	
1. "The Coolest Stars"	Page 12
a) How temperatures are ascertained	
September 1938	
1. "And now the X-Particle"	Page 20
a) New Member in Atomic Family	

## October 1938

1. "Death from the Sky?" Page 173
  - a) Inaccuracy of Airplane Bombing
2. "The X-Particle's New Brother" Page 176
3. "Electrical Rhythms of the Human Brain" Page 186
  - a) Puzzled Science seeks their meaning

## November 1938

1. "Possible Explanation of Brain Waves" Page 236
2. "Artificial Eclipses" Page 240
  - a) An amazing new technique
3. "Cosmic Radiation" Page 246
  - a) Still a Puzzle

"The Need for a Twelve-Year Science Program for the American Public Schools" (A symposium presented before the American Science Teachers' Association, Indianapolis, Indiana, Dec. 30, 1937).  
 Reprinted from *Science Education*, Feb., 1938. Vol. 22, No. 2.

### THE PHYSICAL SCIENCES COURSE—ITS JUSTIFICATION AND SEQUENCE

MR. JOHN C. HOGG, *Phillips Exeter Academy*

About 99% of the boys graduating from this Academy go to college. The work in science is, therefore, of necessity, centered about the College Board Syllabus. During the past seven years we have made investigations to discover how we can best cope with this elusive yet dominating syllabus. "Elusive" because the College Board examiners are no longer bound by the syllabus; "dominating" because, by a change of tactics put into effect last June, no choice of question is now offered so that the omission of any part of the syllabus is now attended by some risk. The outcome of our studies is a variety of courses (ten, to be exact), to meet different needs. The description of these courses, as it appears in the school catalogue, is not easy reading, and it makes heavy demands upon the intelligence of the parent.

The nine instructors of the Science Department are in complete agreement upon a number of points and this accord was the basis of the first diversion from the traditional one-year course. We are agreed that,

- (1) The College Board Syllabus, both in physics and in chemistry is too extensive and diversified for a one-year course;
- (2) Such a course results in superficial work;
- (3) A teacher should have an opportunity to treat selected parts of the syllabus with some thoroughness;
- (4) A science involves new ways of thinking. In fact, for some boys, it is their first course in deductive reasoning, and one year is not enough to make the adjustment.

Some boys inevitably have to take the traditional one-year science course. I say "inevitably" because we have come to regard it as our least satisfactory course. One year of a science is probably of no more value

than one year of a language. Yet, paradoxically, colleges place entrance value on the one and not on the other.

In other cases, however, it is possible for a boy to begin physics or chemistry earlier and so spread it over two years. Minor courses both in physics and in chemistry (and called respectively Physics 1 and Chemistry 1 in the catalogue) were introduced six years ago for boys in grades 10 or 11. (A minor course meets for 2 one-hour recitations a week with a one-hour laboratory period every other week.) In Physics 1 hydrostatics, the structure of matter, and heat are studied. The subject matter is, therefore, free from mathematical difficulties and is well suited to the beginner. Indeed this work is covered more thoroughly than the College Board Syllabus requires. It includes, for example, a thorough treatment of specific gravity, vapor pressure, and the kinetic theory which is presented non-mathematically. This course is an ideal background for the boy who wishes to take chemistry in a later year or to pursue physics. The students in both Physics 1 and Chemistry 1 are invariably enthusiastic and responsive. The teacher, free from the threat of examinations, can turn the enthusiasm to good account.

In the second year, the continuation course is catalogued as Physics 2 or Chemistry 2. It now becomes a major course and the recitations per week are more than doubled. The College Board Syllabus is completed during this year and again there is time to attempt more advanced work. For example, the motion and kinetic energy equations are derived; the magnetometer is used to prove the inverse square law and the conception of potential is carefully developed.

Students grow in maturity and gain in confidence in this second year. It benefits both strong and weak students alike. The weak or inept student is in a sorry plight in the one-year course. He finds himself rushed along in a course for which he may have no aptitude and from which there is no escape. The minor course warns the weak so that they can, if desirable, be diverted, and encourages the strong.

It is to be expected that the student in the two-year course shows a higher average mark, in common examinations, than the boy in the one-year course. This is amply supported by evidence. One of the most encouraging features, however, is the superior work which the two-year student does in college. The gradual trend toward the two-year course at the expense of the one-year course is shown in the following figures. The one-year College Board course is represented by P3 or C3.

1931-32	P3			C3		
	114 students			138 students		
1938-39	P1	P2	P3	C1	C2	C3
	52	34	69 students	58	47	65 students

Courses in biology, physical sciences, and advanced physics and chemistry have also been added and the science enrollment, during this interval, has doubled.

During the two years, 1933-35, we studied the achievement of 50 boys who, in successive years, took physics and chemistry, i.e., P3 followed by C3 or C3 followed by P3. The study is still being pursued but, tentatively, it seems reasonable to make two significant conclusions:

- (1) In the case of the weaker student, the science of the first year gave a marked benefit in the second. This was shown by a higher grade in his second year.
- (2) In the case of good students the high grade is maintained but improvement is not shown. This is what we might expect if a student is not extended. Such a student should be in a graded course, where repetition of work is avoided. The good student is better suited to an integrated course.

It seems reasonable, therefore, to infer that a boy can more profitably study two sciences than one.

It is also interesting to note in passing that the two-science boys show a marked preference for chemistry.

This opinion grows out of numerous expressions of boys during the past six years. The reason for this preference would be interesting and significant. It may be that physics is too philosophical to appeal to young students. It is certain that the dramatic aspect of chemistry makes an early appeal. One of our students, in expressing his preference for chemistry laboratory work, remarked, "In physics, we perform experiments knowing the answer beforehand, but not always understanding the method. In chemistry, the method is always clear and we have to find the answer. There is a good deal of truth in this. There are many different techniques in physics and each problem must be approached differently. In chemistry there are relatively few new techniques so that it is a much simpler matter to get a result.

This argument, obviously, has an important bearing upon the sequence of the integrated course.

There is a growing realization that too much is lost by the separation of the physical sciences. The large number of students who elect to take either physics or chemistry constitutes a grave teaching problem.

The Physics-Chemistry succession is a sound two-year course. But it offers difficulties. If the student elects physics first, he may run into mathematical difficulties for he will require plain geometry, quadratic equations, a little trigonometry and logarithms. Moreover, when he studies electrolysis, measurement of current by chemical effects, the battery, the interchange of potential and chemical energy, he lacks the chemical background. But, frequently, the teacher anticipates these difficulties and omits the borderline topics altogether. If he elects chemistry first, his difficulties are not diminished, for chemistry leans very heavily on physics. The conceptions of pressure, of vapor pressure, of heat, of energy and of static and current electricity are all of fundamental importance in the clear understanding of chemical changes.

These obstacles are purely artificial and do not appear if the subject is

properly approached. A student expects to grapple with difficulties inherent in a subject, but it is unreasonable to subject him to difficulties which arise from an ill-planned course.

The separation of the physical sciences into physics and chemistry was, in the first place, purely arbitrary and made as a matter of convenience. It was never intended that one should be studied without the other. Physics is, for the most part, a study of forces and energy changes while chemistry describes the properties of substances which undergo these energy changes. Physics and chemistry are the complement and supplement of each other. The omission of either leaves an incomplete picture and, even for elementary students, seriously detracts from the value of science as an educational force.

These objections to succession can, of course, be partly met by teaching the two subject concurrently. In this case, however, there would be inevitable overlapping and repetition. Moreover, the demands of other subjects usually preclude a student from pursuing two sciences in the same year. Integration of the two sciences appears, therefore, to offer the solution to this vexing problem.

We, therefore, turned our attention to the integration of the physical sciences as the ideal two-year course. This experiment was begun, in fact, three years ago during which time we have given considerable thought to sequence. In the first year the emphasis is placed on chemistry and the physics is largely utilitarian—it is designed to clarify the chemistry. For this reason, the course begins with hydrostatics, heat, and the structure of matter. Then follows the chemistry of the elements—oxygen, hydrogen, and carbon. Magnetism and electrostatics are studied before ionization is introduced. Roughly one-third of the course is physics and two-thirds chemistry. The following is an outline of the first year's course.

#### SEQUENCE OF FIRST YEAR OF INTEGRATED PHYSICAL SCIENCES COURSE

1. Archimedes' Principle.
2. Air, Pressure; Barometer; Machines Depending upon Air.
3. Expansion.
4. Heat; Calories, Temperatures, etc.
5. Transfer of Heat.
6. Molecular Structure. Cohesion; Adhesion; Kinetic Theory.
7. Vapor Pressure. Humidity, etc. Background to Begin Chemistry.
8. Early Chemistry.
9. Physical and Chemical Changes, Elements, Compounds and Mixtures.
10. Oxygen.
11. Atoms and Symbols.
12. Hydrogen.
13. Formulas and Equations.
14. Water.
15. Chemical Calculations.
16. Combination by Weight and by Volume.
17. Carbon.
18. Carbon Dioxide and Monoxide.

19. Fuels; Treated more thoroughly than ordinarily, because heat has been studied.
20. The Atmosphere.
21. Magnetism.
22. Electrostatics, useful to understanding of nature of electricity.
23. Nature of Electricity, Electrons, Crooke's Tube, etc.
24. Ionization in Solution.
25. Acids, Bases and Salts.
26. Sulfur, Hydrogen, Sulfide and Sulfides.
27. Oxides, and Oxygen Acids of Sulfur.

While there was ample theoretical evidence to guarantee the success of a physical sciences course, yet, in the beginning, we were timid and did not accept the risk involved by allowing boys of the 11th grade to embark upon a new and untried course. We preferred to select boys in the 10th grade for the experimental course. These could recover, if an error of judgment had been made, without serious inconvenience. The result has exceeded our expectations. No boy has failed the course and while only four boys have taken the College Board physical sciences examination, yet they have performed very creditably. Boys in this course are, for the most part, too young to take College Board examinations at the end of the second year and they normally proceed to a third year of advanced chemistry or physics. However, in the common examinations when competing with boys taking the separate courses, the integrated students show a marked superiority. With maturity comes confidence in the second year. It is a common experience that weaker students improve the quality of their work in the second year. This chance is denied the one-year student.

The summary of a recent common examination is shown graphically. The examination was of the objective type, a copy of which is available for any one interested. It covers hydrostatics, heat, and the structure of matter.

Discriminating questions have been collected over a number of years and the reliability of the objective test is shown in the second table. The left column shows the class standing in the physical sciences class at the end of ten weeks. It has been determined by numerous subjective examinations and class quizzes and I doubt if there will be much variation from this throughout the year. The right column shows the class standing indicated by the recent objective tests. The two lists are almost identical. This, in fact, is a common experience.

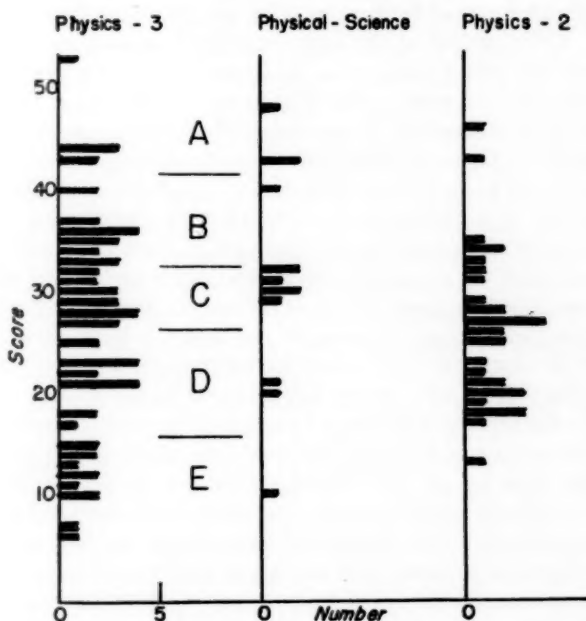
The results of the common examination show that the Physical Science boys have performed, at least, as creditably as the students in Physics 3 despite the difference in age. (The boys in Physics 3 are, at least, one, and usually two years senior to those in the Physical Sciences course.) This result indicates, and experience confirms, that we must dispel the notion that seniority and maturity are essential before we can obtain the serious study of a science. An early beginning, long familiarity and a slow absorption are necessary conditions for the development of the mature mind and the scholarly attitude.

Success with the younger students has given us the confidence to extend the field. In September next, boys in the 11th grade will be admitted.

It has been an interesting experiment in science teaching. At no time did we take a step unless we were convinced the evidence supported it, and even then, we left open a line of retreat by running alternative courses. But there has been no retreat. Evidence accumulates to show that (1) the two-year course in the single subject is superior to the one-year course, and particularly, that (2) the integrated course is superior to the physical sciences taken separately in succession.

### PHYSICS OBJECTIVE TEST

November, 1938



### WHAT THE COLLEGE EXPECTS OF AN ELEMENTARY COURSE IN PHYSICS

J. C. SLATER, *Massachusetts Institute of Technology*

At about this time of year, a procession of freshmen who are failing in our elementary physics course comes to my office. I ask them, among other things, how they are doing in mathematics, and how they did in high school physics. They generally report that they did well in high school, always understood everything and got 98 in the course, but this is entirely different from the high school course, and they don't know what the matter is. And if they are now doing badly in physics, it almost always turns out

that they are doing badly in mathematics too. I should like to ask this morning why this situation exists, and whether anything could or should be done about it.

Of course, it must be realized that our problem at technical schools is much more serious than in institutions which have a less definite need of science. All of our undergraduates must start right in learning physics, and learning it well enough to serve as a foundation for engineering. May I start in by stating a few unpalatable facts, which I hope you will not take as personal criticisms, but as an attempt to be helpful. The high school preparation in physics which most of our students have received is so nearly useless to them in their college work that when the question of dropping physics as a required subject for entrance to the Institute came up several years ago, many of my colleagues did not feel it was worth retaining, though I argued for keeping it on the list of requirements, and it was kept. A comparison of the preparation in mathematics and science received by high school students in this country and in Europe makes the American preparation seem pitiful by contrast. We try at the Institute to train men up to a standard comparable with that reached in European technical schools, but as a result of the undergraduate preparation of our entering students we have to adopt a decidedly difficult curriculum. From the standpoint of technical or scientific training, the tendency of high school educators away from exact science, and toward vague and descriptive courses which are supposed to fit the student to understand the world around him or to be a good citizen, is thoroughly and unreservedly bad.

There are three things, it seems to me, which a high school physics course can do which are of real value in later training. The first is to teach the vocabulary of physics. Every teacher must realize that repetition is essential in the process of learning. One cannot start from the beginning, teach a single course in a subject, and expect the students to have learned that subject once for all. One should properly go over it at least three times: first, to learn what it sounds like, what words are used and what they mean; secondly, to get the general ideas clearly in mind; and thirdly, to master the subject thoroughly enough so that it can be used and applied. In our case, the first of these purposes is accomplished, in general fairly well, by the high school courses, the second by an elementary physics course at the Institute, the third by the more advanced engineering and scientific courses, which generally review the parts of physics which are needed before proceeding with applications.

The study of physics is often the first place in which the student learns to use familiar words, like force and energy and power, in a technical sense. We should have much more difficulty with our college physics than we do if the students did not have a beginning with the vocabulary, and this was the fundamental reason why I favored retaining high school physics as a requirement in our deliberations several years ago. When I speak of vocabulary, I really mean something rather more than that. I mean that the students in the high school course can learn the types of facts and ob-

jects which physics deals with, so that we in our later training of them do not have to stop to talk about levers and Archimedes' principle and such things as if they were new ideas. May I suggest, however, that the high school course is in danger of going too far in filling the student's head with a great mass of detail. From high school physics texts, I get the impression that too many disconnected or trivial facts are taken up. There are a great many more items in such a text than we find time to take up in our two-year elementary course at the Institute. It would be better, it seems to me, to handle fewer topics, but do them more thoroughly.

The second possible useful function of a high school physics course, in my opinion, is one in which most present courses almost totally fail. This is to develop the idea that physics is an exact, mathematical science, and not only to develop the idea, but to teach the students to use their mathematics. Physics, more than any other science, is based on mathematics, and much of mathematics was developed for its application to physics. Yet high school mathematics and physics are almost wholly disconnected, to the great detriment of both. As I hinted at the beginning, the great difficulty which our freshmen find with physics is in the application of mathematics to physical problems. It is here that the greatest contrast to high school physics comes, and it is for this reason that we find such a close correlation between failures in physics and mathematics. Of course, I realize that high school mathematics is not as advanced as college mathematics. Nevertheless, I believe that students who can start in, even though with difficulty, with the study of calculus and its application to physics in their first weeks at the Institute could have used more mathematics in their high school physics.

The mathematical difficulties which the student of physics feels are not so often with mathematical manipulation as they are with the whole idea of applying mathematics to a concrete problem. In particular, while they can do arithmetic (badly) and algebra and geometry (moderately), they have no conception of a functional relation between variables, or of graphical ways of representing these functions. Such concepts are not inherently difficult, and they are very useful, not only in physics but in other fields as well. Both high school physics and mathematics courses would do well to put in more training of this sort, more work in analyzing physical situations in simple mathematical and graphical language, and to make up for it by leaving out many points of detail which now fill up the courses.

The nature of physics as an exact science can be brought out not merely by the use of mathematics, but also by training in careful thinking and detailed analysis of physical problems. An example is the treatment of forces and Newton's laws of motion. We find high school graduates quite unable to separate the forces acting on a body from those exerted by the body, and inspection of high school texts convinces us that this is a result of the vague methods used in high school teaching. Too many students are taught such ridiculous errors as that a body moving in a circle is acted on by a net force of zero, the centripetal force being balanced by an equal and opposite

centrifugal force. Too many of them in problems in statics, draw force vectors along various directions determined by the geometry of the system, and find unknown forces by similar triangles, without ever considering what the forces act on. In our elementary course we spend roughly a quarter of our whole time on Newton's laws of motion and their applications, laying great stress on the exact analysis of mechanical situations. I see no reason why the high school course should not at least put in a good deal more time than it does on such fundamental questions, less on relatively trivial details or applications.

The third useful function of a high school course in physics is to arouse the student's interest and enthusiasm for physics. In every freshman class a few students stand out on account of their quite exceptional apparent maturity. Their attitude is more like that of graduate students than freshmen. They know what they are doing, and how to do it, and on investigation we almost always find that they came from a rather exceptional school. They are not always abler than the other students, but their mature attitude generally is a result of real interest, in contrast to the rather bored and uninterested attitude of many students. The teachers who can inspire their students in this way are rare, and have something of genius which most of us wish we could acquire, but probably more students could be inspired than are, even under the existing circumstances. The really interested students are generally those who have been allowed to go further than the average, either in a second, advanced physics course, which a few of the high schools now have, or by individual work. This is progressive education of the right sort. Let me contrast it with what is more often known as progressive education: the effort to make the students interested by liberating them from restraints, letting them follow their own inclinations, and learn what interests them. We occasionally get students who have had this sort of training, agreeable and enthusiastic boys. But they lack discipline, they are not used to the exact kind of thought needed by science, and they soon fall by the wayside while the son of immigrant parents, from a conventional city high school, forges ahead because he has had to work for what he gets.

The really mature students of whom I just spoke, however, have been trained quite differently. They have had more, not less, discipline than the average. They have been treated as grown up individuals, capable of learning things exactly and analyzing them precisely. They have had the chance of going further than most high school students. And they show the results in a brilliant way. Does it not seem reasonable that other students would profit by similar treatment? I have mentioned that the present high school course accomplished fairly well one of its purposes, teaching the vocabulary of physics, but largely failed in a second, teaching mathematical methods and exact habits of thought. No doubt you will remind me that most of your students do not go on to college, and are constitutionally incapable of exact thought, but will be benefited by a little qualitative, descriptive knowledge of what physics is and what place it has in the

world. I shall agree with you without question, and I believe the present high school physics course is well designed for such students. But you have asked me to talk about your high school courses with reference to later work in college, and it is here that I believe they are very inadequate. The European student going into technical work has a very different high school training from the one who is not going on to the university. My feeling is that the same thing should be true, wherever possible, in this country. Either the students intending to go on with physics should have a different course from the rest, more or less along the lines I have mentioned, or the elementary high school course should be followed by a second, more advanced one, for the exceptional students. Either one of these expedients would, I feel, bring to us students of much better preparation than we have now, not only better able to handle college physics, but with a more interested, enthusiastic, and mature point of view.

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Mr. George N. Northrop, Headmaster of Roxbury Latin School, spoke briefly, giving a most cordial welcome to the members of the Association, and inviting them to inspect the laboratories.

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#### ABSTRACT OF ADDRESS GIVEN BY DR. HARLOW SHAPLEY

Dr. Shapley first stated that astronomers were obliged to modern physics which has provided the tools that have revolutionized astronomy. Some of these are:

1. The image slicer, designed this spring, which speeds up spectrum study 5 to 1 or 7 to 1. The power of the telescope is increased.
2. The Schmidt-type mirror, invented in a few hours by an optician of Hamburg, Germany. The reflecting telescope had a small field, one-fifth of a square degree. The Ross correcting lens gave about 1 square degree. With the Schmidt-type mirror the field becomes 30, 40, or 50 square degrees. This brings the reflecting telescope back into active use, from which it had been displaced.
3. The production of faster red photographic plates, which has pushed the photographic work into the red of the spectrum so that astronomers are not bothered so much by the moonlight, or blue, etc.

\* \* \* \* \*

An enumeration was then made of the most important astronomical observatories in Africa. Those mentioned were;

1. Algiers Observatory.
2. Another observatory in the suburbs of Cairo. This is a government observatory and conducts very little research.
3. Union of South Africa Observatory, which makes more observations per unit of population than any other.
4. The Cape Observatory, the oldest, more than 100 years old. A government observatory devoting most of its time to routine determination of time and radio to shipping, the latter little used.
5. At Pretoria, the Radcliffe Observatory, which will have the largest telescope in South Africa, will be occupied in about a year for study of star spectra.

6. Union Observatory, Transvaal, studies planets and variable stars. The Yale southern station is in the same town, studies parallax of stars along the meridian.

7. University of Michigan Observatory at Bloemfontein, studying double stars.

8. Harvard Observatory, the most active, is carrying on fifteen or twenty different researches, including cosmogony. It is situated in an agricultural region using ox-teams for transportation and on the large farms where sufficient fodder can be grown, with tractors on the smaller farms. The one export is gold.

The observatory has a 60-inch reflector, and employs eight or nine instruments every clear night. The staff is partly white, mostly Boers with a Greek superintendent; and partly black, the latter being mostly Basutus and Zulus.

\* \* \* \* \*

Astronomers used to be interested only in the solar system, later in stellar astronomy, and now in our own milky way. In order to comprehend the universe on a unit basis one must cultivate galaxy astronomy. The difficulties are speeds and immense distances, so that it is a matter of working back in time as well as distance. The focal length of the telescope does not separate the stars of a galaxy to any extent. Galaxy astronomy must be studied away from other stars or black absorbing areas of dust and gas that obscure the count, etc.

To get away from these one must study distant galaxies in order to escape obscuring matter, and at the same time one must get as far as possible from our milky way. The latter is a flattened watch-shaped system in which we are slightly off center. Study has to be done through a comparatively clear space known as a galactic window. We must study away from the plane of our milky way.

Not all of these galaxies are nice spirals. There are spiral ones out in space as we study farther out. A survey for new galaxies 100,000,000 light years or less from the earth is being made and will take about five years more.

A twenty-four inch double telescope is being used, with three-hour exposures, two or three plates per night. This necessitates sitting at the telescope for three hours at a stretch and is the hardest observation in the world. Plates 14 inches by 17 inches are used.

Lantern slides showed the positions of several hundred newly discovered galaxies on one plate. They were not evenly distributed but were bunched more thickly in one place than another, said to show the basic unevenness of distribution of matter through space. All theories have assumed the uniform distribution of matter but perhaps the pendulum has swung too far in the opposite direction.

One plate showed a hazy area patch. It had penetrated space twice as far as any other plate had ever gone, because the plate happened to be twice as sensitive, the night was clear, and the guidance better than usual.

Possible explanations of this patch were; (1) a defect; (2) an open cluster; (3) a globular cluster; (4) a Magellanic cloud; (5) a spheroidal galaxy; or (6) a supergalaxy. These were all eliminated and it was called a sculptor cluster. It is a link between a globular cluster, a Magellanic cloud, and a spheroidal galaxy. There was no detail, no structure; its size was big for a cluster, and not distributed like a galaxy.

\* \* \* \* \*

Forty or fifty people are working on details of the structure of the uni-

verse. They are studying (1) variability; (2) luminosity, (3) distances; (4) evolution; (5) dimensions.

One object is to study Nova, the exploding star. This changes greatly—as much as 1,000,000 times in the amount of en radiation given off in twenty-four hours.

Spectra give the hypothesis of the universe expanding at a definite rate. Magellanic cloud is a galaxy like ours but not so large.

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At the motion of Mr. Rice, a vote of thanks was made to Mr. Northrop and the Roxbury Latin School for the hospitality shown the Association.

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Father Tobin of Boston College invited the Association to hold its next meeting, March fourth, at Boston College, and Dr. Pond, of the Wood's Hole Biological Laboratories extended an invitation to hold the third meeting of the year there, with the possible opportunity of visiting their ship, the *Atlantis*, provided it is not at sea at the time.

Both invitations were accepted.

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## PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON

*State Teachers College, Kirksville, Mo.*

*This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.*

*All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution as on the following pages.*

*The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.*

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## SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.
2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.
3. In general when several solutions are correct, the ones submitted in the best form will be used.

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## LATE SOLUTIONS

1569-1573. Charles W. Trigg, Los Angeles City College.

1568. John F. Wagner, Lewis Institute, Chicago.

1562. Cecil Leith, Scituate, Mass.

1570-1571. O. L. Dunn, Vincennes, Ind.

1573. J. B. King, Corsica, Pa.

1574. Proposed by William W. Taylor, Port Arthur, Texas.

Find the locus of the midpoint of one side of a triangle if the opposite angle is fixed in position and magnitude and the sum of the including sides is constant.

*Solution by T. A. Pickett, So. Weymouth, Mass.*

Construct an isosceles triangle  $ABC$ , with  $AB$  and  $AC$  the equal sides, and each half the given sum. (See diagram)

Select  $N$ , any point on  $AC$ .

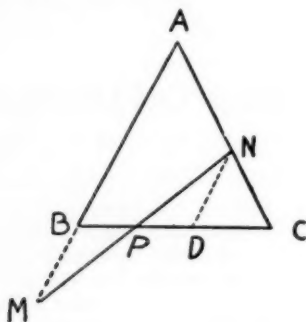
Extend  $AB$  to  $M$ , making  $MB = NC$ .

Draw  $MN$ , cutting  $BC$  at  $P$ .

From the construction  $AM + AN$  is constant, always equal to  $AB + AC$ .

Construct  $ND \parallel AB$ .

It may be easily shown that  $\triangle NDC$  is isosceles, and that  $ND = NC = MB$ .  $\triangle MBP = \triangle NDP$ , and  $MP = NP$ .



Hence the midpoint of  $MN$  is always found on  $BC$ , the base of the  $\triangle ABC$ .

Hence the locus of the midpoint of one side of a triangle if the opposite angle is fixed in position and magnitude and the sum of the including sides is constant is the base of the isosceles triangle formed when the including sides are equal.

Solutions were also offered by O. L. Dunn, Vincennes, Ind., David Gordon, Brooklyn, Arthur Danzl, St. John's College, Collegeville, Minn., John M. Meighan, Harpers Ferry, W. Va., Garland D. Kyle, Knoxville College, Knoxville, Tenn., H. R. Mutch, Aaron Buchman, Buffalo, N. Y., Charles W. Trigg, Los Angeles City College, Walter R. Warne, Minneapolis, Minn., M. Kirk, West Chester, Penn., Sidney Cabin, Brooklyn, and also by the proposer.

1575. Proposed by H. R. Mutch, Glen Rock, Pa.

Solve in integers  $x^2 - 7xy + y^2 = z^2$ .

*First Method*

*By Garland D. Kyle, Knoxville College, Knoxville, Tenn.*

The equation  $x^2 - 7xy + y^2 = z^2$  may be written  $x(x - 7y) = z^2 - y^2$ .

This equation is satisfied by the suppositions  $mx = n(z + y)$  and  $n(x - 7y) = m(z - y)$ ,  $m$  and  $n$  being positive integers.

Hence  $mx - ny - nz = 0$  and  $nx + (m - 7n)y - mz = 0$ .

From the last two equations we have

$$\frac{x}{2mn-7n^2} = \frac{y}{m^2-n^2} = \frac{z}{m^2-7mn+n^2}.$$

Since the given equation is homogeneous, we have as a general solution

$$x=2mn-7n^2, \quad y=m^2-n^2, \quad z=m^2-7mn+n^2.$$

(For instance, if  $m=29$  and  $n=3$ , we get  $x=111$ ,  $y=832$ ,  $z=241$ .)

### Second Method

*Solution by W. R. Smith, Lewis Institute, Chicago.*

Assume

$$x=z$$

then

$$-7xy+y^2=0 \text{ or } y=7x.$$

If

$$x=1 \quad y=7 \quad z=1$$

$$x=2 \quad y=14 \quad z=2$$

$$x=3 \quad y=21 \quad z=3$$

etc.

### Third Method

*By A. L. McCarty, San Francisco Junior College*

$$\begin{aligned} (a^2-7ac+c^2)^2 &= a^4+c^4+49a^2c^2-14a^2c+2a^2c^2-14ac^3 \\ &= (a^2-c^2)^2-7(a^2-c^2)(2ac-7c^2)+(2ac-7c^2)^2. \end{aligned}$$

Therefore  $x=a^2-c^2$ ,  $y=2ac-7c^2$ ,  $z=a^2-7ac+c^2$  is a two parameter solution.

Solutions were also offered by Charles W. Trigg, Los Angeles City College., John F. Wagner, Chicago, Paul H. Renton, Trafford, Pa., Norman Anning, University of Michigan., Thomas A. Pickett, South Weymouth, Mass., John N. Meighan, Harpers Ferry, W. Va., M. Kirk, West Chester, Pa., Sidney Cabin, Brooklyn, and also by the proposer.

**1576.** *Proposed by Norman Anning, University of Michigan.*

Prove that

$$\begin{vmatrix} x & 1 & 0 & 0 & 0 & \cdots \\ 1 & x & 2 & 0 & 0 & \cdots \\ 1 & 1 & x & 3 & 0 & \cdots \\ 1 & 1 & 1 & x & 4 & \cdots \\ 1 & 1 & 1 & 1 & x & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{vmatrix} = \begin{vmatrix} x & 1 & 1 & 1 & 1 & \cdots \\ 1 & x & 1 & 1 & 1 & \cdots \\ 1 & 1 & x & 1 & 1 & \cdots \\ 1 & 1 & 1 & x & 1 & \cdots \\ 1 & 1 & 1 & 1 & x & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{vmatrix}$$

the determinants being of the same order.

*Solution by C. R. Cassity, Tuscaloosa, Alabama.*

Let the determinants be of order  $n$ . In the first determinant, subtract the elements of the second column from those of the first column, the

$$\begin{vmatrix} x-1 & 1 & 0 & 0 & \cdots & 0 \\ 0 & x-1 & 2 & 0 & \cdots & 0 \\ 0 & 0 & x-1 & 3 & \cdots & 0 \\ 0 & 0 & 0 & x-1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & x+n-1 \end{vmatrix} = (x-1)^{n-1}(x+n-1).$$

third column from the second, etc. Then add the elements of the first row to those of the second, the new elements of the second row to the third, etc. The result is as given above.

Subtract the elements of the  $n$ th column of the second determinant from the elements of each of the other columns. Then add all other rows to the  $n$ th row. This gives

$$\begin{vmatrix} x-1 & 0 & 0 & 0 & \cdots & 1 \\ 0 & x-1 & 0 & 0 & \cdots & 1 \\ 0 & 0 & x-1 & 0 & \cdots & 1 \\ 0 & 0 & 0 & x-1 & \cdots & 1 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & 0 & \cdots & x+n-1 \end{vmatrix} = (x-1)^{n-1}(x+n-1).$$

Solutions were also offered by Aaron Buchman, Buffalo, N.Y.; David Gordon, Brooklyn; Charles W. Trigg, Los Angeles City College, and also by the proposer.

**1577.** *Proposed by Mary Foltz, Perry, Iowa.*

Given a circle with radius  $a$ , and a point  $p$  outside the circle at a distance  $a+b$  from the center of the circle.

What is the locus of the midpoints of segments  $p$  to the farther arc of the circle and also to the nearer arc?

#### First Solution

*By John N. Meighan, Harpers Ferry, W.Va.*

Let the center of the circle be at the origin and point  $p$  be on the positive  $x$  axis. Then if  $(x, y)$  is any point on the circle the coordinates of the midpoints of segments  $p$  are:

$$x' = \frac{x+a+b}{2}$$

$$y' = \frac{y}{2}.$$

Hence,

$$4x'^2 + 4y'^2 = a^2 + 2(a+b)[2x' - (a+b)] + (a+b)^2$$

which may be written in the form

$$\left(x' - \frac{a+b}{2}\right)^2 + y'^2 = \frac{a^2}{4},$$

the equation of a circle with center at  $((a+b)/2, 0)$  and radius  $a/2$ .

#### Second Solution

*By Charles W. Trigg, Los Angeles City College*

Let the segment from  $p$  through the center of the circle meet the circle at  $B$  and again at  $A$ . Let any other segment meet the circle at  $F$  and again at  $E$ . Indicate the midpoints of  $Ap$ ,  $Bp$ ,  $Ep$ , and  $Fp$  by  $C$ ,  $D$ ,  $G$ , and  $H$ , respectively. Draw  $AE$ ,  $AF$ ,  $BE$ ,  $BF$ ,  $CG$ ,  $CH$ ,  $DG$  and  $DH$ . Then the angles  $AEB$  and  $AFB$  are right angles, since they are inscribed in a semi-circle. The lines joining the midpoints of two sides of a triangle are parallel to the third side, so

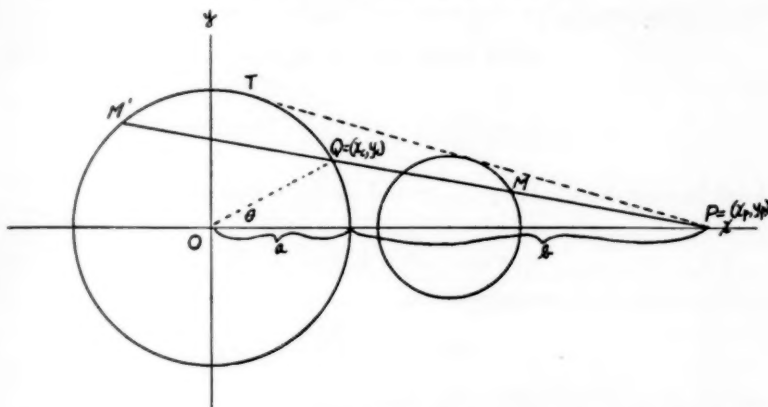
$$CG \parallel AE, DG \parallel CE, CH \parallel AF, \text{ and } DH \parallel CF.$$

Therefore

$$\angle CGD = \angle AEC = \angle AFC = \angle CHD = 90^\circ.$$

Hence the vertices,  $G$  and  $H$ , of the right angles fall on a circle with  $CD$  as the diameter; and as these mid-points were chosen on any segment, their locus is this circle, whose diameter

$$CD = AB + BD - AC = 2a + \frac{1}{2}b - \frac{1}{2}(2a + b) = a.$$



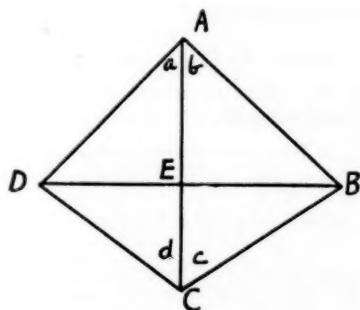
Solutions were also offered by M. Kirk, West Chester, Pa., D. F. Wallace H. R. Mutch, Glen Rock, Pa., Aaron Buchman, Buffalo, N.Y., O. L. Dunn, Vincennes, Ind., and John F. Wagner, Chicago.

1578. Proposed by S. Afpsain, Lucknow, India.

Construct a quadrilateral  $ABCD$  having given all the angles, diagonal  $AC$  and that the diagonals intersect at right angles.

Solution by M. Kirk, West Chester, Pa.

From the figure



$$BE = AE \tan b = CE \tan c \quad (1)$$

$$DE = AE \tan a = CE \tan d. \quad (2)$$

Hence,

$$\frac{\tan c}{\tan d} = \frac{\tan b}{\tan a}. \quad (3)$$

Since  $c = C - d$ , and  $d = 180 - D - a$ ,  
Then,

$$\frac{\tan [c - (180 - D - a)]}{\tan (180 - D - a)} = \frac{\tan (A - a)}{\tan a} \quad (4)$$

$$-\frac{\tan (c + D + a)}{\tan (D + a)} = \frac{\tan (A - a)}{\tan a} \quad (5)$$

This can be reduced to

$$\tan^4 a - k \tan^3 a - k \tan a - 1 = 0. \quad (6)$$

Where

$$k = \frac{\tan A - \tan D + (1 - \tan A \tan D) \tan (D + c)}{\tan a \tan D}.$$

$k$  can be obtained by straight edge and compass. Rewriting (6),

$$\tan^4 a - 1 - k \tan a (\tan^2 a + 1) = 0 \quad (7)$$

$$(\tan^2 a + 1)(\tan^2 a - k \tan a - 1) = 0 \quad (8)$$

$\tan^2 a + 1 = 0$  gives no real solution

$$\tan a = \frac{k \pm \sqrt{k^2 + 4}}{2}$$

can be obtained by straight edge and compass.

Now, draw  $AC$  and construct a circle arc on  $AC$  as chord having the vertex of angle  $D$  on this arc.

Likewise construct a circle arc on  $AC$  as chord having the vertex of angle  $B$  on this arc.

Construct angle  $a$  obtaining point  $D$ . Drop a perpendicular from  $D$  to  $AC$  and extend it to obtain point  $B$ .

**1579.** Proposed by Hugo Brandt, Chicago, Ill.

If

$$\frac{t(3-t^2)}{1-t^2} = \sqrt{3} \quad \text{and} \quad W = \sqrt{t^2+1}$$

and if  $W_0^2(W_0+6) = 8$ , then  $W = W_0$ .

*Solution by Charles W. Trigg, Los Angeles City College*

$t = \sqrt{W^2-1}$ . When this value is substituted in the equation in  $t$ , and the result is squared and simplified,

$$\begin{aligned} W^6 - 36W^4 + 96W^2 - 64 &= 0 \\ (W^3 + 6W^2 - 8)(W^3 - 6W^2 + 8) &= 0. \end{aligned} \quad (1)$$

Clearly every root of  $W_0^2(W_0+6) = 8$  will satisfy (1).

EDITOR'S NOTE:

From the relation  $W = +\sqrt{t^2+1}$ , the values of  $W$  are positive. The roots of  $W^3 - 6W^2 + 8 = 0$  are the negative of the roots of  $W^3 + 6W^2 - 8 = 0$  and are introduced extraneously in the squaring process which obtained (1). Since  $W^3 + 6W^2 - 8 = 0$  has only one positive root, there are only two roots, one from each equation which are equal. However if  $W = \pm \sqrt{t^2+1}$ , then the equations  $W^3 + 6W^2 - 8 = 0$  and  $W_0^2(W_0+6) = 8$  are equivalent.

Solutions were also offered C. R. Cassity, Tuscaloosa, Ala., M. Kirk, West Chester, Pa., Paul H. Renton, Trafford, Pa., Garland D. Kyle,

Knoxville College, Knoxville, Tenn., T. A. Pickett, So. Weymouth, Mass., O. L. Dunn, Vincennes, Ind., and also by the proposer.

### HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

No solutions were offered for this honor roll.

### PROBLEMS FOR SOLUTION

1592. *Proposed by Cecil B. Read, University of Wichita.*

Show that  $(n!)^2 > n^n$

1593. *Proposed by John N. Meighan, Harpers Ferry, W. Va.*

Given a triangle  $ABC$ , with the altitude  $KC$  fixed in position and magnitude. What is the locus of points which divides one of the sides thru  $C$  harmonically?

1594. *Proposed by Cecil B. Read, University of Wichita.*

Find, without the use of calculus, the minimum value of  $\sqrt{a^2 \cos^2 \theta + b^2 \sin^2 \theta} + \sqrt{a^2 \sin^2 \theta + b^2 \cos^2 \theta}$ .

1595. *Proposed by Richard Doner, Syracuse, N.Y.*

Thru a given point draw two transversals which shall intercept given lengths on two given lines.

1596. *Proposed by Walter R. Warne, Minneapolis.*

Four spherical cannon balls of radius one foot each are arranged in a pyramidal pile. Find the height of the pile.

1597. *Proposed by William Taylor, Port Arthur, Texas.*

Show that a triangle may be constructed, given two sides and such that the included angle is equal to one of the angles formed by the third side and the median to that side (third).

## SCIENCE QUESTIONS

February, 1939

Conducted by Franklin T. Jones

*Readers are invited to co-operate by proposing questions for discussion or problems for solution.*

*Examination papers, tests, and interesting scientific happenings are very much desired. Please enclose material in an envelope and mail to Franklin T. Jones, 10109 Wilbur Ave. S.E., Cleveland, Ohio. Thanks!*

*Your classes and yourself are invited to join the GQRA (Guild Question Raisers and Answerers). More than 250 others have already been admitted to membership by answering a question or proposing one that is published.*

BECOME MEMBERS OF THE GQRA

## DO YOU KNOW THE ANSWERS?

26. A valuable prize is offered for the best *scientific* completion of the following:  
 "Prediction: Prosperity will be rising in America when....."  
 .....
27. What is the all-time record for weight lifting?  
 What man? .....  
 When? .....  
 Where? .....  
 Weight? .....
- (Clue: *Collier's* December 3, 1938)
28. Do you know how to make a good chemical kindling to carry on a camping trip?
29. How does the meniscus of water differ from that of mercury?
30. How cold is "liquid air"?

## ANSWERS

1. (833—*How do cows sleep?*)

*Answer by Mr. Beryl Bracewell. (Elected to GQRA, No. 257.) Lancaster Consolidated Schools, Lancaster, Minn.*

"Dear Mr. Jones:

On page 1040 of SCHOOL SCIENCE AND MATHEMATICS, you state "Cows sleep on their right side and lay their heads over against their left side." There is not the least semblance of truth in this statement. For the sake of figures, I made a little survey after reading this statement. In a herd of 17 cows, 12 were lying down, 5 of which were lying on their right sides and 7 on their left.

16. Are we walking "feet up"? No. Our feet are normally on the ground and that is "down."
17. The convex rear vision mirror shows *more of the road* than a plane mirror.
18. Modern windshields (and rear windows) are inclined to prevent reflection of lights into eyes of drivers. They are inclined enough to throw reflected rays up away from range of driver's vision.
19. The Great Meteor of 1860 was the greatest meteor ever seen on the American continent. It passed over Lake Erie from west to east at 9:15 P.M. on July 20, 1860, as a great fiery ball. In five minutes it had passed over Pennsylvania and New York, swept the full length of Long Island and exploded somewhere beyond Barnegat Light.
20. Propose a question that 100 readers of SCIENCE QUESTIONS will answer.

*Send in your "Do You Know the Answers" questions.*

## GQRA—NEW MEMBERS

257. Mr. Beryl Bracewell, Lancaster, Minnesota.  
 258. Thecla Kau, Mercy High School, Milwaukee, Wis.  
 259. C. B. Harrington, Newton High School, Newtonville, Mass.  
 260. Mary Virginia Rogers, Mercy High School, Milwaukee, Wis.

*Other contributions from:*

- No. 148. W. A. Porter, Chisholm, Minn.

## TEST IN SOUND (CONTINUED FROM JANUARY)

850. Proposed by H. Emmett Brown, GQRA No. 255, Lincoln School, Teachers College, Columbia University.

In the remainder of the items, a variety of kinds of situations are described. You are to react to the situation by marking statements in various ways. Read each problem carefully and note any special directions that may be given.

36. Two identical tuning forks of the same frequency, mounted on reinforcing bases are used in an experiment in a classroom. On the tine of one of these, which we will call fork *A*, a small clamp is placed. The other fork, fork *B*, is left unaltered. Both forks are hit blows of equal force at the same instant. The vibrations of each fork last for over a second.

Check those statements that are true in this situation.




- a. The frequency of fork *A* is greater than that of fork *B*. . . ( ) a.
  - b. There will be a small number of beats produced each second. . . . . ( ) b.
  - c. The joint effect of the two notes will be to produce a discord. . . . . ( ) c.
  - d. The note produced by fork *A* will travel at the same speed as that produced by fork *B*. . . . . ( ) d.
  - e. The amplitude of the first notes produced by fork *A* will be greater than those produced toward the end of the first second. . . . . ( ) e.
  - f. It is not possible that the notes produced by fork *A* should be of the same pitch as the notes produced by fork *B*. . . ( ) f.
  - g. The first wave produced by fork *B* will be about 1100 feet from the fork at the end of the first second. . . . . ( ) g.
  - h. The particles of air carrying the sound vibrates at right angles to the direction in which the waves are moving. . . ( ) h.
  - i. The waves sent out by fork *A* are of longer wave length than those sent out by fork *B*. . . . . ( ) i.
  - j. The notes produced by fork *A* will be louder than those produced by fork *B*. . . . . ( ) j.
  - k. The note sent out by fork *B* contains no overtones. . . . ( ) k.
  - l. The wave form of the note sent out by fork *B* has a regular form with little, if any, irregularity. . . . . ( ) l.
37. A stenographer, working in a busy office, is found to do unsatisfactory work both as respects amount and quality. Her recommendations from previous employers are excellent, and her typing records, both as respects speed and accuracy are considerably above the average. The stenographer claims that the noise in the office is preventing her from doing her best work. Her claim is:
- a. absurd. . . . . ( ) a.
  - b. reasonable. . . . . ( ) b.
- Check the statements that you think are true in this situation.
- c. Noise causes undue amounts of fatigue. . . . . ( ) c.
  - d. With time the stenographer can so condition herself that the ill effects produced by the noise will disappear. . . . ( ) d.
  - e. With time, even though no definite attempts be made to accustom herself to the noise, the effect of the noise on the nervous system will become less and less. . . . . ( ) e.
  - f. The loud noises of the office increase the pressure on her brain. . . . . ( ) f.
  - g. There have been no careful studies made of the effect of

- noise upon the ability of people to do work..... (   ) g.  
 h. Small amounts of noise cause stimulation for a time.... (   ) h.

*Check those of the following statements that you think represent a proper policy for the owner to follow.*

- i. Since none of the other girls complained, the employer is justified in concluding that the complaint is unjustifiable (   ) i.  
 j. He should take steps to determine the actual amount of noise present in the office..... (   ) j.  
 k. He should secure the cooperation of all employees to reduce the volume of noise in the office..... (   ) k.  
 l. The employer's responsibility does not extend to matters of this report..... (   ) l.
38. Sounds of the same energy content produce the same sensation of loudness when:  
 a. they are of the same pitch and quality..... (   ) a.  
 b. they are of the same pitch..... (   ) b.  
 c. they are of the same quality..... (   ) c.  
 d. they are of the same pitch and overtone content..... (   ) d.  
 e. they are of the same pitch and frequency..... (   ) e.
39. We performed an experiment in which we were able to see a wave form which resulted when we spoke into a speaking tube which was part of a certain piece of apparatus. Among the things which this experiment is designed to show are:  
 a. the wave lengths of the sounds of a woman's voice are normally longer than those of a man's..... (   ) a.  
 b. the fact that musical tones may have a variety of wave forms..... (   ) b.  
 c. that a musical note may have a wave form that is quite irregular, so long as certain portions are of the same form and continually recur at regular intervals..... (   ) c.  
 d. that it is the consonants that really carry the sound.... (   ) d.  
 e. that louder sounds produce wave forms that extend to greater distances from the line of zero displacement than do weak sounds..... (   ) e.

*In order that any, or all of the statements checked should be capable of demonstration with the apparatus it is necessary that:*

- f. the rotating mirror revolve at speeds appropriate to the various experiments..... (   ) f.  
 g. that the source of light be at right angles to the small mirror which is caused to vibrate by the sounds entering the tube..... (   ) g.  
 h. that the speed of revolution of the rotating mirror be synchronous with the vibration rate of the small mirror.. (  ) h.  
 i. that the screen on which the wave form is projected be in a straight line with the beam of light from the source..... (  ) i.  
 j. the person performing hum at a constant pitch..... (  ) j.

*(The balance of this Test on Sound—40 to 44 inclusive—will be published in March, 1939.)*

### PLEASE TIME YOURSELF

*On 850, please do the following:*

1. Teacher, time yourself on the above instalment.

2. Time your best pupil at some appropriate stage of your instruction in the future.
3. Send your results on 1, to the EDITOR NOW. *Thanks!*
4. Send your results on 2, when you obtain them.

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### BOOKS AND PAMPHLETS RECEIVED

*Photography Principles and Practice*, by C. B. Neblette, Counselor and Administrative Head, Department of Photographic Technology, Rochester Athenaeum and Mechanics Institute. Third Edition. Cloth. Pages xi+590. 15×23 cm. 1938. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y. Price \$6.50.

*Introduction to Bessel Functions*, by F. Bowman, Head of the Mathematics Department in the College of Technology, Manchester; formerly Scholar of Trinity College, Cambridge. Cloth. Pages x+135. 13.5×21.5 cm. 1938. Longmans, Green and Company, 114 Fifth Avenue, New York, N. Y. Price \$3.60.

*Enriched Teaching of Mathematics in the Junior and Senior High School*, by Maxie Nave Woodring, Professor of Education, Teachers College, Columbia University, and Vera Sanford, Head of Department of Mathematics, State Normal School, Oneonta, New York. Revised Edition. Cloth. Pages x+135. 15×23 cm. 1938. Bureau of Publications, Teachers College, Columbia University, New York, N. Y. Price \$1.75.

*Projective Questions in College Chemistry*, by Alexander Calandra, Tutor, Department of Chemistry, Brooklyn College, Brooklyn, New York. Paper. Pages viii+151. 21×27.5 cm. 1938. The Chemistry Book Store, 786 East 21st Street, Brooklyn, New York.

*Chemistry and You*, by B. S. Hopkins, Professor of Inorganic Chemistry, University of Illinois, Urbana, Illinois; R. E. Davis, Head of the Chemistry Department, Lane Technical High School, Chicago, Illinois; H. R. Smith, Head of the Chemistry Department, Lake View High School, Chicago, Illinois; Martin V. McGill, Head of the Chemistry Department, Lorain High School, Lorain, Ohio; and G. M. Bradbury, Head of the Science Department, Montclair High School, Montclair, New Jersey. Cloth. Pages ix+802. 13×20.5 cm. 1939. Lyons and Carnahan, 2500 Prairie Avenue, Chicago, Ill.

*Offerings and Registrations in High-School Subjects, 1933-34*. Text Prepared by Carl A. Jessen, Senior Specialist in Secondary Education and Tables Prepared under Direction of Lester B. Hirlehy, Associate Specialist in Statistics. Bulletin 1938, Number 6. 96 pages. United States Department of the Interior, Office of Education, Washington, D. C. For sale by the Superintendent of Documents, Washington, D. C. 15 cents.

*Brooklyn Botanic Garden Record*. Second Edition. July, 1938. Volume xxvii, Number 3. Paper. 255 pages. 14×23 cm. Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn, N. Y. Price \$2.50.

*Major Issues in Financing Education in Pennsylvania*, by Lester K. Ade, Superintendent of Public Instruction. Bulletin Number 135. Pages v+99. 15×23 cm. 1938. Commonwealth of Pennsylvania, Department of Public Instruction, Harrisburg, Pa.

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*Pennsylvania Program of Literacy and Citizenship Education*, by Lester K. Ade, Superintendent of Public Instruction. Bulletin 293. 83 pages. 15×23 cm. 1938. Commonwealth of Pennsylvania, Department of Public Instruction, Harrisburg, Pa.

## BOOK REVIEWS

*An Analysis of Proofs and Solutions of Exercises Used in Plane Geometry Tests*, by Hale Pickett, Ph.D. Published with the approval of Professor William D. Reeve, Sponsor. Contributions to Education, No. 747, Bureau of Publications, Teachers College, Columbia University, New York City. Cloth. 1938. Pages 120. 15×23 cm. Price \$1.60.

The book is the outcome of a study in which proofs and solutions of exercises used in plane geometry tests were analyzed. The writer collected geometry tests for the years 1923–1935 from five different sources. The sources and number collected follow:

Source	Number
a. Annapolis Entrance Examinations	26
b. College Entrance Board Examinations	18
c. Regents Examinations	26
d. Selected State Examinations	67
e. West Point Entrance Examinations	13
Total	150

The writer solved most of the exercises and the balance were solved by graduate students, who in turn checked the writer's solutions and each other's. Upon analysis of the solutions it was found that only two theorems were used as reasons in proofs in 90% or more of the cases involving proof; two in 80% to 90%; and three in 70% to 80%. Furthermore, only 16 theorems were used as reasons to answer 50% or more of the cases involving proof.

The sixteen theorems require too much space to be listed here but the reader will find it profitable to read the book. The study shows a list of only 58 theorems needed to solve the problems in the 150 examinations.

JOSEPH J. URBANCEK, Lane High School, Chicago

*Introductory Mathematical Analysis*, by Joel S. Georges, Ph.D., Chairman of Department of Mathematics, Wright Junior College, Chicago; and Jacob M. Kinney, Ph.D., Chairman of Department of Mathematics, Woodrow Wilson Junior College, Chicago. Cloth. Pages xv+605. 15.5×23.5 cm. 1938. The Macmillan Company, New York. \$3.00.

A large portion of the books in introductory mathematical analysis remind one of a glorified drug store sandwich—a layer of this, a layer of that, put together without any clear object in view except to produce a new creation, which may, by its mere novelty, appeal to someone. It is indeed refreshing to find a text with some definite aim, which seems to have been *written*, not merely compiled from previous books. The underlying theme, to quote from the preface, is the concept of function. "The concept of function is used as a unifying principle about which the various concepts and processes of the course are correlated." Certainly something has produced a text far more unified than is usual.

At first glance, the arrangement of material and the order of topics seems astounding. Solid analytical geometry is introduced before the study of the circle. Power functions, and even the treatment of maxima and minima by methods of the calculus appear before the student encounters in this text the quadratic formula. Volumes of solids of revolution, by the integral calculus, appear before the analytic equation of the circle. The treatment of the slope of a curve appears before the study of the six trigonometric functions. It seems impossible, yet by a well chosen sequence of topics, these violations of traditional arrangement are not only made possible, but

one wonders why such an effective treatment was not discovered before.

At the end of each chapter appears a cumulative review. In many cases the questions presented are stated in the form which a student will very probably encounter in an objective examination. These reviews would make good examinations over the material of the chapter. There is an abundant supply of numerical exercises as well as many other problems presented under the heading of "Discussion." These range from simple questions to the development of theory. As an illustration, a very good discussion of symmetry in polar coordinates is developed by the use of this type of problem.

Certain material encountered is not common, for example, a page on abbreviated multiplication and division; a unique method for obtaining the derivative of the sine and cosine; a very clear notation showing the operations performed in solving linear equations; a single rule for determining the characteristic of a logarithm (the characteristic is the exponent of 10 when the number is written in scientific notation).

According to the authors, the material can be covered in a five-hour course for two semesters. How adequate this covering would be is somewhat debatable, certainly there is an abundance of material.

The intent seems to have been to develop a working knowledge of mathematics, rather than to spend time on rigorous proof of all the details. It should not be understood that proofs are lacking except in certain cases, as for example in Descartes' Rule of Signs. Probably this attack has much in its favor but at certain points one wonders if the student might not get into difficulty. Such a situation might arise in an attempted use of infinite series, for there is essentially no discussion of the question of region of convergence. In fact, one could assume from the statement on page 349 that the series for  $\log(l+x)$  is valid for all negative values of  $x$ .

The appearance of the book is excellent, no misprints were noted in going over the book. A few minor points were noted, the first being in the definition of a tangent to a curve, on page 25. The omission of the condition that the variable point must approach the fixed point *along the curve* might permit any line radiating from the origin to be a tangent to certain spirals. From the discussion in the text, it would be hard to answer the question (on page 79) as to the number of significant figures in 27,800. In the discussion of Newton's method it is not made clear that without proper selection of the value used as a first approximation to a root, the second approximation may be less accurate than the first. For the inverse cotangent, secant, and cosecant, the definition of the principal values given on page 436 would be in contradiction to that used in many texts.

The only glaring error noted was on page 459, where it is stated that the function  $x = e^{-t/4} \sin t$  has maximum values for  $t = \pi/2, 5\pi/2$ , etc. The bright student will immediately discover that these values do not make the first derivative (given in the same article) vanish.

CECIL B. READ, University of Wichita

*High School Chemistry*, by George Howard Bruce, Department of Chemistry, Horace Mann School for Boys, Teachers College, Columbia University. Cloth. Second Revision. Pages x+550. 14×19 cm. 1938. World Book Company. Yonkers-on-Hudson, New York, Price \$1.68.

The second revision of this book was made to bring it up-to-date. However, one finds the Birkeland-Eyde process and the Le Blanc process discussed. It is stated that metallic sodium and potassium are prepared industrially by the electrolysis of their fused hydroxides even though the du Pont Corporation has not used this method for at least ten years in their Niagara Falls plant.

A random sampling reveals some contradictory statements which lead only to confusion, such as on page 295 "Nitrogen pentoxide is the anhydride of nitric acid" while on the same page the statement is made that "nitric acid is formed by the reaction of nitrogen dioxide and water."

The statement is made on page 147 that "neutralization is the reaction of an acid and a base to produce water and a salt" while on page 227 the statement is made that "Neutralization is essentially the union of the hydrogen ions of an acid and the hydroxyl ions of a base to form undissociated molecules of water." On page 226 "whenever an acid and a base are brought together in a solution a salt and water are formed" while on the same page "Really nothing happens in a neutralization reaction except the combining of the H and OH ions."

Common sense and reasonableness are used to explain the electrolysis of water. Complete dissociation is claimed for the strong electrolytes. The drawings are exceptionally clear and well labeled. Approximately twice as much material is included as should be attempted by the average class in one year of work. An appendix contains tables of physical data. Indexed.

DRULEY PARKER

*Experimental Units in Biology*, by J. Frank Faust, Principal Chambersburg High School and George R. Biecher, Head Teacher of Biology, Chambersburg High School, Chambersburg, Pennsylvania. Cloth. Pages ii + 404. 14.5 × 19.5 cm. 14 illustrations and diagrams. Stackpole Sons, Harrisburg, Pennsylvania. 1938. Price \$1.60.

This book is an elaborate work guide, it is not a workbook in the sense that it provides blank spaces to fill in. The book is divided into sections called Experience Groups. Each experience group is divided into units. There is a total of 19 units. Each unit is given a time limit. Each unit is followed by an achievement item called Essentials to Have Derived from This Unit. This appears to be an outstanding item in the organization of this book. Besides the above, each unit is followed by a good word list and an exceptional reference list for this type of work. The procedure is worked out in considerable detail. The book gives the impression that the vehicle used for student achievement is the progressive "learn by doing principle." Plenty of opportunity is provided for student activity. Among the last pages of the book are some good understandable diagrams on egg and sperm generation and fertilization.

A. G. ZANDER

*Color Photography for the Amateur*, by Keith Henney, Editor of *Electronics*; Author of "Principles of Radio" and "Electron Tubes in Industry," Editor of *Radio Engineering Handbook*. Cloth. Pages x + 281. 14 × 20.5 cm. 1938. McGraw-Hill Book Company, 330 West 42nd Street, New York, N. Y. Price \$3.50.

Amateur photography has long been one of the outstanding educational hobbies. The greatest development in photography in recent years is the use of selected frequencies for particular situations such as the use of infrared radiation for penetrating haze. Color photography is one phase of the use of selected frequencies for reproducing natural colors for transparencies or for prints on paper. Color photography is both difficult and expensive, hence the art has not been rapidly extended to the amateur field. The author of this book has evidently made a serious study of both the theory and the technical details of all phases of color photography and has written a book to help amateurs save both time and money in mastery of this

fascinating hobby. The book tells how to make transparencies, negatives and paper prints by all the various processes in commercial use. The apparatus and supplies needed are listed and the processes described. Numerous cautions and common errors are given. The book presupposes a rather thorough knowledge of black-and-white photography but gives the color processes in minute detail.

G. W. W.

### MOTION PICTURE REVIEWS

The two reviews of motion pictures that follow are in the nature of trial balloons. It is planned that they shall continue if we receive indication that these reviews are of some value to teachers. It is not planned to review all of the recently released films. That is obviously impossible. What is planned, is to review one or more films suitable for use in science classes, with reasonable care, and critically, so that science teachers may gain some idea of the kind of film that is being produced today and some appreciation of critical standards for judging films. The reviews may be of value to producers in this latter connection also. The review will not be limited to sound pictures, although that was the case this time. The reviewing committee was informally organized but was composed of science teachers in the Teachers College environment who have had considerable experience with the use of films. In subsequent reviewing groups it is hoped to have representatives of not only the subject-matter fields but also both elementary science and the science of the high school.

The divisions into which the review has been cast are not necessarily fixed. The reviewing committee welcome your suggestions either for new headings or for specific points that you would like to have covered under whatever headings are used. Send your suggestions either to the editor of this magazine, or to H. Emmett Brown, Teachers College, Columbia University, New York City.

*Fingers and Thumbs.* Distributed by Walter O. Gutlohn, 35 W. 45th Street, New York City and Ideal Pictures Corporation, 30 East 8th Street, Chicago, Ill. 2 reels, 16 mm. Sound. Rental price \$4.00. Sale price \$100 less 20% to schools.

#### *1. The Story of the Film.*

This film shows how the hand of man with its opposing fingers and thumb have been developed through the evolutionary process throughout the ages. Opening scenes make the point that the first hand was really the front fin of some primitive marine ancestor. Pictures of a modern mud-skipper are then shown to suggest how this fin may have been modified for use both on land and in water. Soon the true amphibian of which modern frogs and toads are prototypes appeared. At this point in the film, scenes of boys catching tadpoles are used to introduce a study of these creatures.

Subsequent development and modifications are related to a general plan of a hand, which, as a sort of X-ray sketch of bony structure is now shown. We then see how the hand has undergone modification in the course of the animals taking to the air or to life on the plains. In each case we see how the general model of the hand has been modified for flight or locomotion. Among the creatures that are shown are the elephant with its massive, pedestal-like legs, the seal with its forelimb modified to form a flipper, and the bat. With certain animals, too, evolution has proceeded in such a way that the hand is not used for support and the type of development characteristic of the marsupials is the result.

The film then passes to a consideration of the hand of typical monkeys and finally to that of the apes whose hands are shown to have such a construction as to make it possible for them not only to pick up, but also to rotate objects—a feat impossible to owners of less highly developed fingers and thumbs. It is seen that the ape has a hand which makes it possible for him to do many of the things that man does. Final scenes of a baby are used to emphasize the essential similarity of the hand of man and that of the highest of the simians.

## *II. Criticism of the Film as a Teaching Aid.*

Excellent as the film may be in other respects, the spoken commentary does much to destroy the usefulness of the film as it presents the theory as a scientifically proved fact. In the explanation, teleological, or near teleological reasons are frequently used. In addition to the teaching of such scientific inaccuracies a procedure of this sort may close the minds of many students to the essential reasonableness of the theory of evolution. Furthermore, such treatment interferes with, rather than promotes, scientific thinking.

In addition to the above criticisms there are some errors in the naming of organisms. The commentary refers to insects when photographs of lobsters, centipedes and scorpions are shown. Likewise frogs and toads are confused.

In the hands of an alert and skillful teacher, the weaknesses of the narrative might serve as teaching material for training in scientific method and scientific thinking. But used by any other teacher, the sound track of this film may do much to negate the excellent teaching value of the photography.

## *III. Technical Qualities of the Film.*

The sequences of this film are well photographed, interesting, and in general well articulated. They contain much good teaching material for classes in biology on the secondary level or upward. It is doubtful if the musical background accompanying the narrative contributes to the educational value of the film. The film is British in origin but the accent of the narrator is not sufficiently marked as to interfere with understanding or otherwise to grate on American ears.

## *IV. Rating.*

1. Age level: Secondary School and above.
2. Quality of photography: Excellent.
3. Selection of scenes: Average. (Extraneous material included. Some material understressed.)
4. Quality of narration. Poor. (Inaccurate at places, and often unscientific.)

*Underground Farmers.* Distributed by Walter O. Gutlohn, 35 W. 45th Street, New York, N. Y., and by Ideal Pictures Corporation, 30 E. 8th Street, Chicago, Ill. 1 reel, 16 mm. Sound. Rental, \$1.50. Sale price \$50 less 20% to schools.

### *I. The Story of the Film*

The "underground farmers" of the film's title are a colony of ants who grow a type of fungus for food in a subterranean chamber eight feet below the surface of the ground. The story of how the inhabitants of this colony, through their diversity of size, structure, and function, are able to carry

out the numerous activities necessary for the life of the colony is the theme of the film. Thus we see one group of ants which climb trees in order to cut the leaves which furnish the basis for the growth of the fungus. Once the leaves or portions of leaves, are cut, they are carefully carried down the tree to the ground where their bearers are joined by others bringing twigs and blossoms for the colony. Still other groups of ants are concerned with the actual cultivation of the subterranean garden. The great diversity of size in this colony is illustrated by the warrior ants which are fifty times larger than some of the other types.

In the final scenes of the picture, another colony of ants, called "harvester" ants because they gather plant seeds for food, sally forth to overcome the challenge offered by the establishment of the rival colony of "farmer" ants in the neighborhood. The whole picture offers interesting parallels to human activities, but in these particular scenes the parallel is markedly close, since the war of the ants is wholly economic in character. The defending ants are defeated but in their defeat contrive to cover over the opening of their colony with small stones and the colony is saved.

## *II. Criticism of the Film as a Teaching Aid.*

The commentary is explicit and well selected. One observing the film critically doubts some of the statements made in regard to the battle staged between the two warring colonies. However, this does not seriously impair the usefulness of the film.

The film was first prepared for general theatrical use and was released for that purpose in April, 1936. Because of the general nature, certain features of the typical classroom film—detailed study, animated diagrams, etc.—are lacking. The film is nevertheless excellent in its appreciative aspects.

This film may be used for its nature study aspects, for its ecological aspects, for illustrating the life history of ants, and for the study of their social organization.

## *III. Technical Qualities of the Film.*

The photography is truly remarkable, it is not only clear but is possessed of real beauty. The film presents the story of the busy life of ants with an economy of time yet with sufficient completeness.

## *IV. Rating.*

1. Age level—Useful at all levels.
2. Quality of photography—Excellent.
3. Selection of scenes—Excellent.
4. Spoken commentary—Good.

Reviewing Committee:

N. ELDRED BINGHAM,

F. T. HOWARD,

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